Annotated Bibliography:

Information and Studies Relevant to Interim California Forest Practices Rules for Watersheds with Threatened or Impaired Values

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by CH2M HILL, Inc.

Contents

Author's Background and Qualifications

Dr. Steve Mader is Senior Habitat Management and Planning Scientist, and Senior Technologist, with CH2M HILL, Inc., where he has specialized in forest and wetland ecology for 15 years. Additionally, he is a Certified Senior Ecologist (Ecological Society of America), Certified Forester (Society of American Foresters), and Professional Wetland Scientist (Society of Wetland Scientists). He has been performing projects for public and private sector clients, including the forest industry, in California, Oregon, and Washington, and has performed numerous environmental studies related to the National Environmental Policy Act (NEPA), Clean Water Act (CWA), Endangered Species Act (ESA), and natural resources and land use permitting and compliance for projects in the western United States.

His specific technical and academic training is in the science of forested wetlands and riparian areas, and he has performed silvicultural research and contributed to the development of forestry best management practices for forested wetlands. His Ph.D. is in Forestry/Ecology, and he holds a M.S. degree in Silviculture and a B.S. degree in Forest Biology.

Since 1976, he has been actively pursuing forest policy issues as an active member of the Society of American Foresters. He received a Certificate of Appreciation award for his support of SAF's involvement with President Clinton's 1993 Forest Conference, and he reviewed and assisted with the formulation of SAF position statements on controversial professional forestry issues such as the SAF Task Force Report on *Sustaining Long-term Forest Health and Productivity*; the 1993 Forest Ecosystem Management Assessment Team (FEMAT) Report on *Forest Ecosystem Management*; and the Draft Supplemental Environmental Impact Statement on *Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl*. Also, he assisted with the SAF review of the federal Interior Columbia Basin Ecosystem Management Project.

In 2000, he co-authored the *Analysis and Comments for the Proposed Forest Practices Rule Package: Protections for Threatened and Impaired Watersheds* (CH2M HILL, Inc. 2000), and delivered testimony to the California Board of Forestry and Fire Protection on proposed forest practice rules, entitled *Protections for Threatened and Impaired Watersheds*. Subsequently, he co-edited a literature review of the salmon and sediment history of Redwood Creek, California; and prepared a forest practices review of the Cassidy Timber Harvest Plan in California. Also, he prepared a declaration and expert report for the defendants in Case No. C00-0713 SC in the United States District Court for the Northern District of California (EPIC et al. v. Andrea Tuttle et al.). The case concerned the State of California's regulation of private timber harvesting, specifically concerns about violating Endangered Species Act provisions protecting coho salmon through promulgation of forest practice rules.

He assisted the Oregon Forest Industries Council with technical reviews of scientific literature used in the development of revised forest practice rules, water temperature standards, and Clean Water Act Total Maximum Daily Loads (TMDLs) in Oregon. Other projects include expert testimony on riparian vegetation for the Devil's Lake Water Improvement District; review of the best available science for riparian area protection in Spokane County's Critical Areas Ordinance; effects analysis for NMFS/USFWS's NEPA review of the Plum Creek Timber Company's Native Fish Habitat Conservation Plan; and reviews and comments on the federal

Interior Columbia Basin Ecosystem Management Project for the Northwest Forestry Association and Intermountain Forest Association.

Dr. Mader participated with a team of environmental scientists with expertise in riparian area management, fisheries science, geological hazards, and cumulative effects analysis to perform a review of the scientific foundations of the *Forests and Fish* plan for forest practice rules in Washington. The overall project objectives were to evaluate whether the strategies, guidelines, and prescriptions in the plan were supported by the scientific literature applicable to specific sections of the proposed rules. The summary report, which found the rules to be adequate based on known data and documentation, was presented to the Washington Forest Practices Board on April 20, 2000 (CH2M HILL. 2000. *Review of the Scientific Foundations of the Forests and Fish Plan*. Washington Forest Protection Association, Olympia, WA). Subsequently, he reviewed the DEIS on *Alternatives for Forest Practices Rules for Aquatic and Riparian Resources*, and on April 19, 2000 he presented oral testimony before the Washington Forest Practices Board, pursuant to SEPA, on the DEIS's alternative that represents the recommended rules of the *Forests and Fish Report*; and signed a declaration in support of summary judgment in *Washington Environmental Council v. United States Environmental Protection Agency*, No. C00-1549R (W.D. Wash.). In that declaration he explained how the *Forests and Fish Report* provides reasonable and prudent measures for managing riparian areas and assuring compliance with water quality standards.

Executive Summary

This annotated bibliography identifies and summarizes recent scientific and technical studies, many performed in California watersheds, that can and should influence forest practices rulemaking in California, particularly the interim Forest Practices Rules for Watersheds with Threatened or Impaired Values. The new knowledge of riparian forest ecology and management interactions was generally unavailable at the time the interim rules were adopted, and it builds on the foundation of information and perspectives compiled in the report, *Analysis and Comments for the Proposed Forest Practices Rule Package: Protections for Threatened and Impaired Watersheds* (CH2M HILL, March 2000).

Recent advances focus on three categories of scientific endeavor: (1) the ecology of watercourse and lake protection zones (WLPZ) and their biophysical limitations for influencing aquatic habitats; (2) control of erosion and ecological effects of sediment delivery; and (3) analysis of the potential cumulative effects of forest management. Many of the findings describe conditions under forest practices rules that were in place before the interim rules were adopted; others reveal new insight about legacy influences.

Coupled with the prior knowledge, these recent contributions provide better understandings of: (1) the baseline water temperatures and sediment delivery conditions of forest watersheds; (2) the limitations on biophysical effects of forest practices that influence water temperature and sediment delivery; and (3) the ecological risks of potential harm to protected species or violation of water quality standards if a biophysical effect is possible. Also, research shows that the science of cumulative watershed effects is seriously imperfect for use as a forest practices regulatory tool.

Some significant findings are:

- Sediment delivery to watercourses can be controlled most appropriately and significantly through improved drainage structure design, construction, and maintenance along forest roads (e.g., Cafferata and Munn 2002; Rice 1999).
- Forest-related erosion is a very small (<5%) component of surface erosion within 200 feet of the stream when compared to other natural erosion processes; surface erosion in clearcut harvest units was found to be negligible to non-existent; and post-fire surface erosion rates dominate surface erosion over the long-term (e.g., Benda 2004).
- WLPZs have physical limits for influencing aquatic habitat conditions and functions (e.g., Chan et al. 2005; James 2003).
- Wood recruitment in some streams is dominated by non-forest mortality sources, and 90% of wood volume recruitment may occur within narrow riparian zones less than 50-60 feet wide. An important finding of these California-based studies is that large wood habitat forming pieces were produced primarily by bank erosion sources (e.g., Benda 2003, 2004).
- Water temperature effects of forest practices are controllable and not cumulative beyond the reach scale (e.g., Lewis et al. 2000; James 2003; Cafferata and Munn 2004).

- WLPZs along Class I streams with buffers of 50-ft to 100-ft can be thinned without significant reduction of shade or water temperature change, and these narrow vegetative buffers are sufficient to protect the water quality and near-stream microclimate of small streams (e.g., James 2003; James 2004).
- Class II streams have limited ability to contribute to the desirable aquatic conditions of downstream Class I reaches (e.g., Benda January 2004).
- WLPZs along Class II streams can be thinned without significant reduction of shade or change in water temperature, and narrow vegetative buffers may be sufficient to protect small streams (e.g., Chan et al. 2005).
- Some forest practices rules require expensive technical studies to implement, or cannot be implemented as written in many or most forest watersheds (e.g., Wright 2004; Matthews 2003; McBain & Trush 2000; Andras et al. 2005).
- Enforcement of rules regulating potential cumulative effects of forest practices is based on hypothetical biophysical relationships because appropriate data and analytical procedures are lacking, or are as yet untested (e.g., MacDonald et al. 2003; Andras et al. 2005).
- Inherent spatial and temporal variability of forested watersheds suggests that short-term sediment production needs to be placed in the context of long-term background erosion rates to provide meaningful interpretation of results (e.g., Kirchner 2003; Andras et al. 2005; NCASI 1999).
- Limitations of science need to be taken into account when formulating regulations (e.g., Benda et al. 2002).

Knowledge gained through past and recent forest practices research and monitoring studies suggests approaches and criteria for improving current California forest practices rules intended to avoid take of federally-listed species or water quality impairment. Findings of research and monitoring efforts challenge assumptions of the interim California Forest Practices Rules for Watersheds with Threatened or Impaired Values for avoiding take or violation of water quality standards, and reinforce concerns about the appropriateness of implementing fairly rigid prescriptions across the broad ranges of variability exhibited by the state’s forest resources. Individually or as a whole, the findings of this compendium fail to support the necessity for the interim California Forest Practices Rules for Watersheds with Threatened or Impaired Values, when compared to the standard rule protections they replaced.

Introduction

This annotated bibliography of *Information and Studies Relevant to Interim California Forest Practices Rules for Watersheds with Threatened or Impaired Values* has been prepared to assist the Board of Forestry and Fire Protection (Board) when it decides whether the rules are needed any longer. It was prepared as an effort of the California Forestry Association, and their members.

The following body of knowledge complements and should be considered together with previous information provided to the Board by CFA in a document titled, *Analysis and Comments for the Proposed Forest Practices Rule Package: Protections for Threatened and Impaired Watersheds* (CH2M HILL, Inc. 2000). That report concluded that many of the interim rules are unsupported or inconsistently supported by the scientific literature, and are generally imprecise when applied across a broad geographic area—although some interim rules may be more conservative than the prior rules. Furthermore, the 2000 report found that the interim rules do not reflect numerous forest practices monitoring reports that generally indicate the appropriateness of rule flexibility for addressing local site conditions, and made the case that prior rules were doing a good job for conserving ecological values and steadily improving environmental conditions. At about the same time period, the Board's Monitoring Study Group found that individual practices required by the FPRs are effective in preventing erosion when properly implemented, and results mostly pointed to a need for better training and implementation, not stricter rules (Brandow et al. 2006; Cafferata and Munn December 2002).

This collection of scientific and technical studies is not intended to be comprehensive. Rather, it includes work that is most likely to weigh on the Board's pending decision. Most of the information and studies became available after the *Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat* was prepared for The Resources Agency of California and the National Marine Fisheries Service in June 1999 to comprehensively review the California Forest Practice Rules (FPRs) with regard to their adequacy for the protection of salmonid species. A few annotations are older, but warrant special attention for their potential utility. Most of the citations are relevant to multiple subsections of the interim rules. Additional scientific references, without annotations but also relevant to the interim rules, are included at the end of this bibliography.

This annotated bibliography is organized primarily by three categories of watershed effects addressed by the interim forest practices rules:

- Limitations on the Ecological Influence of Watercourse and Lake Protection Zones
- Control of Erosion and Effects of Sediment Delivery
- Cumulative Effects Analysis

Within each of the three categories, information and studies are listed alphabetically by author. Each contribution contains:

1. A complete bibliographic citation.
2. A statement of the objectives or subjects addressed.
3. A summary of the significant findings.
4. A conclusion suggesting the relevance of the information to the interim California Forest Practices Rules for Watersheds with Threatened or Impaired Value.

Limitations on the Ecological Influence of Watercourse and Lake Protection Zones

1. Anderson, Paul D., David Larson, and Samuel S. Chan. 2005. **Riparian buffer and upslope density management influences on microclimate of young headwater forests of western Oregon.** P. 12. In: Oregon Headwaters Research Cooperative. November 2005. Symposium on the Science and Management of Headwater Streams in the Pacific Northwest. Oregon State University, November 17-18, 2005. Oregon Headwaters Research Cooperative, Corvallis, OR.

Objective:

i. Investigate the influences of buffer widths (ranging from 23 to 213 feet wide) and upslope density management treatments on riparian and adjacent upslope microclimates associated with headwaters streams of Cascade and Coast Range forests of western Oregon.

Key Findings:

- Regardless of thinning intensity, all but the narrowest buffers were effective in maintaining microclimate at stream center similar to that in unthinned stands.
- When buffers of 50 feet width or greater were retained, air temperatures at stream center differed by less than 0.5 °C and relative humidity differed by less than 4% from that for unthinned stands.
- In unbuffered thinned stands, late-afternoon air temperature was 1 to 4 °C greater and relative humidity as much as 1% less, relative to unthinned stands.
- Through five years after thinning, summer air and soil temperatures increased and relative humidity decreased with upslope distance from the stream. Gradients were strongest within 33-50 feet of stream center.

Relevancy:

1. FPRs should recognize that riparian buffers as narrow as 50 feet are effective for managing forest microclimate along small streams.

2. Benda, Lee. January 2004. **Little North Fork Noyo River Wood Budget, Mendocino County, California.** Prepared for Campbell Timberland Management, Fort Bragg, CA. Lee Benda and Associates, Inc., Mt. Shasta, CA.

Objectives:

i. To determine the rates of wood recruitment by forest mortality, bank erosion, and streamside landsliding.

ii. To estimate wood loading from historical logging activities.

iii. To estimate bank erosion and forest mortality rates using wood budgets.

Key Findings:

- The wood budget for the LNF Noyo River basin indicates that the majority of wood originates from non-mortality sources, specifically bank erosion.
- Significant spatial variation in wood storage was observed, partly driven by spatial variation in the dominant recruitment processes, including bank erosion and streamside landsliding.
- Stochastic models of watershed processes, including wood recruitment, wood transport, and sediment production, illustrate the generally unpredictable and stochastic behavior of watersheds.
- Wood was the dominant pool former in most reaches. Wood storage and recruitment rates exhibited high spatial variability (hundreds to thousands of percent) at the 100 m (328 feet) reach scale due to variation in recruitment processes and in amounts of historical logging debris.
- On average, logging debris comprised 22% of the total in-stream wood. Bank erosion comprised 81% of wood recruitment followed by mortality (11%), landslides (6%), and debris flows (2%). Approximately 90% of the wood enters the channel from within 8 m (26 feet) (slope distance) of the stream edge because bank erosion was the dominant recruitment process.
- Total wood storage ranged from 2 to 95 m^3/100 m and averaged 18 m^3/100m. Wood recruitment rates averaged 2.1 $m^3\ km^{-1}\ yr^{-1}$ for all processes combined, with 0.3 $m^3\ km^{-1}\ yr^{-1}$ for mortality, 1.6 $m^3\ km^{-1}\ yr^{-1}$ for bank erosion, and 0.2 $m^3\ km^{-1}\ yr^{-1}$ for landsliding. Ages of log jams and distances between jams reflect instream wood transport. Debris jam age (average 30 years) decreased with increasing drainage area indicating increasing wood transport and decreasing jam stability downstream. The distance between debris jams averaged 73 m (240 feet) and interjam spacing showed an increasing trend downstream. Assuming that in-stream wood survives approximately 100 years before decaying (using an average 3% yr^{-1} decay rate), predicted transport distances over the lifetime of wood averaged 440 m (1,444 feet).
- Based on stand surveys of trees greater than 10 cm (4 in) in diameter near in-stream wood survey sites, conifers comprised over 90% of the riparian forest with average riparian forest biomass of 515 $m^3\ ha^{-1}$. Forest mortality rates for conifer and deciduous trees averaged 0.3% yr^{-1} and 0.1% yr^{-1}, respectively—the low rates may be due to predominance by redwoods.

- Average bank erosion rates for larger, fish bearing streams was estimated to be 7 cm yr^{-1}, a rate that may reflect continuing incision and lateral migration of the channel because of past logging that either filled channels with sediment or otherwise altered their hydraulic geometry. A bank erosion sediment flux for 3rd and higher order channels of 410 t km^{-2} yr^{-1} was calculated for the LNF Noyo. In the context of other independent estimates of sediment yield along the Mendocino Coast, the calculated sediment flux from bank erosion is a major component of the LNF Noyo's sediment budget. More specifically, the rate of 410 t km^{-2} yr^{-1} for fluvial bank erosion is inconsistent with the estimated bank erosion sediment input rate of 77 tons km^{-2} yr^{-1} contained within the Noyo River total maximum daily load (TMDL) for sediment (U.S. EPA 1999) based on the "desk top" sediment budget of Graham Matthews & Associates (GMA) (1999). This suggests that the EPA TMDL for the Noyo River has underestimated the bank erosion component of the sediment budget by approximately 500% and consequently the "background" sediment yield by 250%, despite the claim by the EPA in the Noyo River TMDL (1999) that "the 77 tons km^{-2} yr^{-1} [for bank erosion] is likely an overestimate…"

Relevancy:

1. The high degree of spatial variability documented in LNF Noyo River basin questions the efficacy of developing regulatory wood loading targets for streams and monitoring programs to verify compliance.
2. Effects of past logging activities may dominate present erosion and sediment yield—a mostly unalterable situation for present day forestry activities.
3. The apparent underestimation of the bank erosion component and the background sediment loading contained within the EPA TMDL for the Noyo River suggests that the use of quantitative values (from the TMDL) should be treated with significant caution and potentially not be used for establishing quantitative thresholds for monitoring.
4. The dominance of non-mortality sources of wood recruitment indicates that design of buffer strips for wood recruitment should consider for prioritization landforms prone to bank erosion and stream side landsliding.
5. Source distances for wood recruitment greatly depend on whether bank erosion or streamside landsliding are important processes; forest mortality is typically a tertiary process in wood recruitment.
6. Design of buffer strips might be most effective at a site specific basis, in which the width of the buffer strip will vary along a stream according to variations in wood recruitment processes.
7. Information on wood transport indicates that only the lower portions (< 200 m or 656 feet) of small, headwater non-fish bearing streams contribute wood to larger, fish-bearing channels.

3. Benda, Lee. March 2004. **Wood Recruitment to Streams; Mendocino Coast, California.** Prepared for Campbell Timberland Management, Fort Bragg, Ca. Lee Benda and Associates, Inc., Mt. Shasta, CA.

Objective:

i. To summarize the wood budgets of the Little North Fork (LNF) Noyo River watershed, and Bear Haven and Redwood Creek subbasins located in the Ten Mile watershed, both catchments located close to Fort Bragg, California.

Key Findings:

- Historical logging-related woody debris accounted for 49% of all wood storage in 17 km (11 miles) of study reaches.
- Wood recruitment to streams is dominated by non-forest mortality sources (i.e., bank erosion and streamside landsliding): 64% in Ten Mile, and 85% in the Noyo River basins.
- Ninety percent of wood recruitment (by volume) occurs within 14 m (46 feet) and 8 m (26 feet) of stream edges in the Ten Mile and Noyo watersheds, respectively.
- Average wood jam age ranged between 30 and 40 years; average wood jam spacing ranged between 50 and 100 m (164-328 feet). Wood transport (over the lifetime of wood in streams) is predicted to range between 150 and 1,300 m (492-4,265 feet) depending on stream size. In headwater systems, only the lower 200 meters of channel are predicted to contribute wood to larger fish-bearing channels (transported wood should be only several meters long).
- Significant spatial variability of wood storage indicates that continuous channel surveys of 4,000 to 10,000 m or more (2.6 to 6+ miles) are necessary to estimate a reliable average value of wood loading.
- Ten Mile Watershed: Field-based estimates of erosion by soil creep and streamside landsliding in the wood budget are 750% higher than those sediment sources estimated in the EPA Ten Mile “desk top” sediment budget and associated TMDL. This suggests that the Ten Mile TMDL has underestimated “background” sediment production by approximately 500% and overestimated the recent timber harvest contribution to sediment yields by approximately 300%.
- Noyo River Watershed: Field-based estimates of soil creep are significantly greater (~500%) compared to the EPA Noyo River “desk top” sediment budget and TMDL. Consequently, the EPA TMDL may have underestimated background sediment yields by approximately 250%.

Relevancy:

1. Forest practices rules addressing wood in streams should recognize that wood recruitment in some streams is dominated by non-forest mortality sources (i.e., bank erosion and streamside landsliding), and that 90% of wood volume recruitment may occur within narrow riparian zones only 26 to 46 feet wide.
2. Natural variability in wood recruitment and storage within stream reaches suggests that establishing regulatory targets for the purpose of conducting compliance monitoring for

wood is questionable in the naturally dynamic and spatially heterogeneous riparian environments.

3. For two watershed examples—the Ten Mile and Noyo River Watersheds—EPA's sediment budgets and TMDLs are not sufficiently accurate to base "allocated loads" or other quantitative measures of compliance for resource management.

4. Benda, Lee E., Paul Bigelow, and Thomas M. Worsley. 2002. **Recruitment of wood to streams in old-growth and second-growth redwood forests, northern California, U.S.A.** Can. J. For. Res. 32: 1460–1477.

Objective:

i. An analysis was made of the mass balance of in-stream wood along 9 km (5.6 mi) of channels in old growth and 50-year-old second-growth redwood forests in northern California.

Key Findings:

- High volumes of wood storage in streams in old-growth forests were due primarily to streamside landsliding and bank erosion. Logging-related debris and high forest mortality rates in conifer and deciduous forests contributed to high wood storage in second-growth forests. Volumes of in-stream wood in second-growth forests were similar to volumes in one old-growth system and less than another. Diameters of wood were significantly greater in older forests.

- Wood recruitment from forest mortality in old-growth forests was low compared with second-growth sites, driven by differences in conifer mortality rates of approximately 0.04 and 0.9%·year–1, respectively. Contrasting old-growth redwood mortality with values reported for unmanaged Douglas-fir forests in Washington State (0.5%·year–1) and unmanaged Sitka spruce forests in southeastern Alaska (1.2%·year–1) point to a strong latitudinal gradient of forest mortality reflected in tree size. The mass balance analysis of in-stream wood also allowed an estimation of bank erosion along large channels and soil creep along small, steep streams.

Relevancy:

1. In-stream wood storage in second-growth forests can be as high as the amount in old-growth forest systems.

2. Wood recruitment from forest mortality is higher in second-growth sites than old-growth forests.

5. Berg, N., A. Carlson, and D. Azuma. 1998. **Function and dynamics of woody debris in stream reaches in the central Sierra Nevada, California.** Can. J. Fish. Aquat. Sci. 55: 1807-1820.

Objective:

i. To describe the function and dynamics of woody debris in streams, including stability, geomorphic function, and use by fish for cover.

Key Findings:

- While woody debris was often associated with habitat units in streams of the central Sierra Nevada, few pieces deflected flow or contributed to the formation of pools or steps.
- In the 60 study reaches, debris was not influential in shaping channel morphology and fish cover. Although woody debris was often associated with habitat units, few pieces deflected flow or contributed to the formation of pools or steps.
- Fish used deep water as cover more often than debris or any other cover type. However, medium-sized debris was used in greater proportion than its availability to fish.
- Little sediment was stored by debris, and five large pieces stored 85% of the sediment volume measured.
- Debris frequency and volume did not differ significantly by channel type.
- After a low stream flow year (1993–1994), few pieces had moved and few new pieces were identified. After a high-flow season (1994–1995), 31% of the pieces had either moved or were not found and new pieces represented over 5% of the originally surveyed volume of wood.

Relevancy:

1. This report demonstrates some of the limitations of woody debris in streams for influencing the quality and complexity of fish habitat. These limitations should be considered during the development of FPRs to regulate wood recruitment and storage, and the effects of forest practices on fish and their habitat.

6. Burns, James W. 1970. **Spawning bed sedimentation studies in northern California streams.** Calif. Fish and Game 56(4): 253-270.

Objectives:

i. To monitor the effects of logging on silver salmon and trout habitat in the redwood and Douglas-fir forests of northwestern California.

ii. To describe changes in spawning bed composition accompanying logging and associated road building.

Key Findings:

- Spawning bed composition in four test streams changed after logging, roughly in proportion to the amount of streambank disturbance.
- Narrow streams (Little North Fork Noyo River and South Fork Caspar Creek) with small gravel or pebble bottoms were adversely affected by streambank disturbance. The largest stream (Bummer Lake Creek), with a cobble and boulder bottom, was not as easily eroded.
- Road location is an important consideration in streambed sedimentation. Roads on low gradient slopes or located more than 30 m (100 feet) from the stream generally did not contribute to spawning bed sedimentation.
- Spawning bed recovery may be rapid or may take several years. The riffles in streams with relatively stable flows generally accumulate sediments more readily than those with very high peak flows. Fine sediments are readily flushed out by freshets once the source of erosion is removed. Once logging is completed, suspended solids markedly decrease from concentrations observed during logging.

Relevancy:

1. CDFG determined that logging-related sedimentation was greatest during periods of road construction near streams and debris removal.
2. Forest practices that limit road building on steep slopes or within 100 feet of streams can reduce sedimentation to insignificant or recoverable levels.
3. Spawning beds recover from sediment loading by flushing flows. Stream hydraulics influence the rates of recovery.

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7. Burns, James W. 1971. **The carrying capacity for juvenile salmonids in some northern California streams.** Calif. Fish and Game 57(1): 44-57.

Objectives:

i. To define the natural carrying capacity of juvenile coho (silver) salmon, steelhead rainbow trout, and coast cutthroat trout in seven coastal streams; that is, the greatest weight of fishes that a stream can naturally support during the period of least available habitat.

ii. To develop methods of population comparison and prediction that could be used to determine the effects of road construction and logging on salmon and trout production.

Key Findings:

- The hypotheses that streams reach carrying capacity in the summer, and that biomass per unit of living space is constant from one year to the next, must be rejected. Salmonid biomass in unlogged streams was highly variable and changed considerably during the study.
- Even with 3 years of prelogging study, it would be difficult to attribute a change in carrying capacity under 50% to anything but natural variation.
- Fish biomass per unit of surface area is the best method of expressing carrying capacity. Only living space variables correlated significantly with biomass. It does not appear that physical and chemical factors will prove to be useful factors for predicting carrying capacity.
- The most direct way to assess the impact of logging on anadromous salmonids is to compare numbers of juvenile outmigrants before and after logging. This method is generally impractical in California because outmigration is extremely seasonal. Therefore, an index of natural carrying capacity was developed.

Relevancy:

1. Forest practices rules should reflect that streams do not reach carrying capacity in the summer.
2. Fish biomass per unit of living space is highly variable from one year to the next—the natural variability of fish carrying capacity is greater than the effect of timber harvesting on fish.

8. Burns, James W. January 1972. **Some effects of logging and associated road construction on northern California streams**. Trans. Amer. Fish. Soc. 101(1):1-17.

Objective:

i. To investigate the effects of logging and associated road construction on four California trout and salmon streams, based on measurements of streambed sedimentation, water quality, fish food abundance, and stream nursery capacity.

Key Findings:

- Logging was found to be compatible with anadromous fish production when adequate attention was given to stream protection and channel clearance.
- The carrying capacities for juvenile salmonids of some stream sections were increased when high temperatures, low dissolved oxygen concentrations, and adverse sedimentation did not accompany the logging.
- Studies suggest that logging is compatible with anadromous fish production if adequate attention is given to stream and watershed protection and channel clearance. Under special circumstances, stream salmonid production can even be enhanced by logging. (Cold streams, shaded by dense forest canopies are not optimum trout habitats. Thinning the riparian canopy allows a greater total solar radiation to reach the stream, raising temperatures a few degrees, and increasing the production of bacteria, algae, and the insects upon which fish feed.) Salmonid biomass increased in two California streams after the streams were carefully logged.
- Extensive use of bulldozers on steep slopes for road building and in stream channels during debris removal caused excessive streambed sedimentation in narrow streams.
- Sustained logging prolonged adverse conditions in one stream and delayed stream recovery.

Relevancy:

1. Forest practices rules should reflect facts that: (1) most sediment delivery to streams can be controlled by avoiding direct disturbances to streambeds and steep slopes by heavy equipment; (2) careful thinning in riparian areas may improve fish habitat quality; and (3) dispersed harvest planning facilitates stream recovery if impacts occur.

9. Cafferata, Peter. October 1990. **Temperature regimes of small streams along the Mendocino Coast.** Newsletter of the Jackson Demonstration State Forest 39:1-4.

Objective:

i. To summarize studies of the temperature regimes of small coastal drainages, and how they are impacted by timber harvesting.

Key Findings:

- Small coastal streams in Mendocino County provide valuable anadromous fish habitat.
- Prior to timber harvest operations in second-growth forests, maximum stream temperatures are generally below 60° F. Full exposure to solar radiation, as was permitted before modern Forest Practice Rules went into effect, sometimes allowed unacceptable temperature increases to occur.
- For the two case studies, large temperature increases did not occur from clearcut harvesting with buffer strips.

Relevancy:

1. Forest practices should consider buffer strips along all streams bearing fish to reduce the potential adverse impacts of increased stream temperatures due to logging.
2. Effective buffer strips for temperature control are those which leave the trees and shrubs that actually produce shade to the stream during the critical summer months of the year.
3. The size of a stream, its orientation to the sun, surrounding topography, type and density of vegetation, stability during windstorms, and damage from logging and slash burning need to be considered when designing a buffer strip.

10. Castelle, Andrew J. and A.W. Johnson. 2000. **Riparian Vegetation Effectiveness.** National Council for Air and Stream Improvement, Inc., Research Triangle Park, NC. Technical Bulletin No. 799.

Objective:

i. To summarize the body of scientific knowledge of riparian vegetation effectiveness, as related to timber harvesting and buffer size.

Key Findings:

- Most of the potential shade to streams for water-temperature compliance comes from the riparian area within 75 feet (23 m) of the channel.
- Riparian vegetation "sink functions" generally increase rapidly with increasing buffer size for buffer widths up to about 25 or 30 m; beyond this size, disproportionately large increases in buffer width are necessary to markedly improve riparian function. With respect to sediment trapping from runoff, most of the benefit of riparian vegetation is manifested within the first 5-25 m (16-82 feet). Other factors include infiltration and evaporation, thus reducing runoff, while downed trees may provide a significant barrier to sediment movement. Streambank stability was found to be a function of fine root density within the bank itself, in addition to a function of several intrinsic soil parameters, but not buffer width.
- "Source functions" of riparian vegetation were found to be generally highest near streams and decreased with increasing distance from the stream. Vegetated buffers of up to 25 m (82 feet) in width provide significant large organic debris, particulate organic matter, and shade production. As with the sediment trapping curves, disproportionately larger buffers are needed to increase effectiveness for these functions from about 75% to 95% or greater.
- Variable-width buffers allow greater flexibility for varying site conditions and land management practices. Variable-width buffers can be tailored to existing site conditions and desired functions, eliminating the need to protect features non-existent in an area. The quality of buffer and site conditions should be considered in determining a buffer width.
- Buffers of prescribed widths may not adequately protect the riparian system, and may unnecessarily restrict land uses. They are less effective than management techniques adapted to local topography and natural disturbance regimes. In other cases, a smaller buffer may adequately protect the stream and riparian community.

Relevancy:

1. Shade management prescriptions of the FPRs do not have the potential to cause basin-wide cumulative temperature effects.
2. Variable-width buffers allow flexibility for land management practices, while maintaining ecological functions.

11. Chan, S.S., P.D. Anderson, R.J. Danehy, and M. L. Reiter. 2005. **Riparian microclimate, overstory canopy and understory vegetation and soil moisture relationships to a range of timber harvest prescriptions in headwaters forests of the central Oregon Coast Range**. P. 19. In: Oregon Headwaters Research Cooperative. November 2005. Symposium on the Science and Management of Headwater Streams in the Pacific Northwest. Oregon State University, November 17-18, 2005. Oregon Headwaters Research Cooperative, Corvallis, OR.

Objectives:

i. Identify and characterize those features that delineate headwaters riparian areas from upland forest.

ii. Evaluate the effects of various timber harvest activities on those features.

Key Findings:

- Upland relative density (RD) averaged 32 in unharvested stands and 21 in thinned stands. Streamside density of thinned stands (RD 31) was similar to that of unharvested stands.
- The percentage of radiation penetrating the forest canopy at stream center averaged 57%, 10%, and 3% for clearcut, thinned, and unharvested stands, respectively. Summer maximum air temperatures and minimum relative humidities at stream center differed between the clearcut (32 °C; 38%), thinned (27 °C; 46%), and mature (20 °C; 61%) stands. Maximum streambed temperatures were similar in thinned and unharvested stands and about 2 °C less than those for clearcuts.
- A narrow vegetative buffer of trees or dense shrubs along headwater streams in clearcuts lowered insolation at the stream and resulted in microclimates similar to those surrounding headwater streams where forest thinning occurred.
- Soil moisture did not differ among harvest type, but was substantially greater at 15 m (50 feet) than 5 m (16 feet) from stream center.
- Irrespective of harvest type, strong microclimate gradients occurred within 5 m (16 feet) of stream center and upland conditions were observed within 15 m (50 feet) of the stream.

Relevancy:

1. FPRs for managing canopy shade along small streams should recognize that riparian areas can be thinned without significant reduction of shade or water temperature.
2. A narrow vegetative buffer of trees or dense shrubs may be sufficient to protect small streams within clearcuts.
3. FPRs should recognize that the influence of small streams on riparian microclimate may only extend 16-49 feet from the stream into vegetated buffers.

12. Hines, David and Jonathan Ambrose. 2000. **Evaluation of Stream Temperatures Based on Observations of Juvenile Coho Salmon in Northern California Streams.** Campbell Timberland Management, Inc., Fort Bragg, CA and National Marine Fisheries Service, Santa Rosa, CA.

Objective:

i. To define stream temperature thresholds for coastal streams of northern Mendocino County, using field observations of juvenile coho salmon rearing.

Key Findings:

- The existing method of setting MWAT thresholds using temperature magnitude limits is not the most biologically relevant approach because it correlates poorly with presence and absence.
- The best statistical model suggests that the number of days a site exceeded an MWAT of 17.6 °C was one of the most influential variables predicting coho salmon presence and absence. Certain habitat variables, in combination, also influenced the model, suggesting a synergistic interaction among variables controlling the distribution of juvenile coho salmon. Of the habitat variables, pool depth was the most influential.
- Stream temperature thresholds used as water quality standards for the protection of juvenile coho salmon habitat should take into account the amount of time a site is at or above a given temperature (i.e., time-of-exposure). A meaningful threshold can be defined at or below average conditions for habitats where coho salmon are present. However, it must be understood that this does not necessarily represent ideal conditions. This approach would be no less restrictive than a conventional MWAT threshold, yet it seems to provide a stronger relation to fish habitat selection in northern California. Because fish presence does not necessarily signify optimal environmental conditions, further field investigations into the condition of the fish should be performed as an additional biological foundation for the establishment of any threshold proposed as a standard of protection.

Relevancy:

1. Stream temperature thresholds should incorporate a time-of-exposure limit within a significant range of temperatures rather than the single MWAT magnitude limit.

13. Ice, George, Dennis Schult, Patricia Olson, Sam Chan, and Sherri Johnson. October 2001. **Heat Transfer in Forested Watersheds – Final Proceedings Report – October 2001; Summary Report; CMER/RSAG Temperature Workshop – 2001.** Prepared for the Washington Department of Fish and Wildlife. EDAW, Inc., Seattle, WA.

Objectives:

i. To summarize the proceedings and discussion from two workshops on the subject of heat transfer processes in forested stream environments. The workshops, held in Lacey, WA in February and May of 2001, were organized as part of the Cooperative, Monitoring, Evaluation, and Research (CMER) program, and sponsored by the Riparian Scientific Advisory Group (RSAG).

ii. To identify where scientific consensus exists and where it is lacking on heat transfer processes in forested watersheds, to provide overviews of past and current research, and to identify future priorities based on stakeholder review of this information. Specific topics addressed included:

   a. The effects of direct solar radiation to surface waters and the cumulative effects of heating from upstream sources;
   b. Currently used temperature models, addressing their inputs, strengths, and weaknesses;
   c. Heat transfer processes via groundwater; and
   d. Heat transfer processes via microclimate conditions (both in the riparian zone and over the stream).

Key Findings:

- **Solar Insolation.** Solar insolation (i.e., direct solar radiation to the water's surface) is the dominant source contributing at least 90% of heat energy to surface water. Although other heat sources received considerable attention in recent years, validation of these effects is lacking and they represent a minor percentage (<10%) of the overall amount.

- **Microclimate.** Successful measurement of a microclimate effect on surface water temperature has been elusive. Careful studies have not been able to measure a microclimate effect on water temperature where there was a buffer 50 feet wide or greater. Where buffers are narrower or absent, it becomes impossible to separate the microclimate effect from the more significant solar insolation effect.

  Water temperatures will always move towards equilibrium with the surrounding air. However, elevated air temperature occurs only during the middle of the day. Air has a significantly lower heat capacity than water, thus it takes significant time for air to bring a body of water into equilibrium. Furthermore, microclimate effects from timber harvest are a combination of three effects; higher mid-day air temperatures, lower mid-day humidity, and higher wind speeds. The latter two effects combine to increase evaporation from the water's surface, which has a cooling effect on water temperature.

- **Solar Tracking.** A better measure of solar insolation would to measure the shade in the path of the summer sun, i.e., solar tracking, rather than measuring the shade from the entire 'view to sky' (e.g., manual densiometer method).

- **Groundwater.** More research is needed to determine forest practices induced groundwater effects on surface water temperature. Relatively little is known with certainty.
- **Headwater Temperature Transfers.** Surface water temperature in headwater streams did re-establish temperature equilibrium with air upon re-entering shaded stream reaches. The distance and time that it takes to re-establish equilibrium is a function of many variables.
- **Areas of Non-Consensus**. There were no major areas of non-consensus among the panelists.

Relevancy:

1. Solar Insolation. No future research is needed to validate the fundamental effects of solar insolation.
2. Solar Insolation Measurement. Research is needed on the most effective measure of solar insolation. Densiometers are time consuming to use and readings are subjective.
3. Solar Tracking. Research on this subject as it applies to forest channels is sparse. If solar tracking proves to be a better predictor of water temperature response, this would create flexibility to manage for other riparian functions on the north bank of stream channels. Evaluation of tools for measuring shade along summer solar pathway is needed.
4. Headwater Temperature Transfers. Additional research is needed to validate the distance and/or time needed to achieve equilibrium with surrounding physical conditions.
5. Microclimate. In light of recent findings and current riparian buffer requirements, additional research on the effects of microclimate on water temperature is a low priority, given data logger technology.
6. Groundwater effects. Research on groundwater is in a very early phase of development. Both the theory and field methodology need development. There is a need for a conceptual model of heat transfer to groundwater, and then from groundwater to surface water.
7. Hyporheic Exchange. Johnson and Jones 2000 suggested that hyporheic heat exchange in alluvial streambeds and valley floodplains could have a significant effect on surface water temperature. (The hyporheic zone is the transitional zone between the stream aquatic ecosystem and other groundwater systems). It appeared to be considerably more significant than the microclimate effect. Other studies also suggest this effect may be under-rated. If significant, the restoration of bedrock channels that were historically alluvial channels, and the restoration of incised channels may be legitimate methods for water temperature restoration. It is unclear whether forest management practices can negatively alter or even impact the hydrologic process of hyporheic exchange.

14. James, Cajun E. 2003. **Southern exposure reach project: A study evaluating the effectiveness of riparian buffers in minimizing impacts of clearcut timber harvest operations on shade-producing canopy cover, microclimate, and water temperature along a headwater stream in northern California.** PhD Dissertation, University of California, Berkeley, CA.

Objective:

i. To examine timber harvesting effects on water temperature, shade producing, canopy, and the near stream microclimate in the Judd Creek watershed, a tributary of the North Fork Antelope Creek (and the Sacramento River).

Key Findings—Water Temperature:

- Heat Source modeling showed little predicted change in stream temperature in the 1.5-mile Judd Creek experimental reach with complete removal of vegetation beyond 50 feet and during low summer discharge (~2 cfs).

- Heat Source modeling predicted that daily average and daily summer maximum water temperatures would remain essentially unaffected by reduction of buffer width from 175 feet (calibration condition) to ~100 feet, and that water temperature would increase less than 0.3 ^{o}C due to timber harvesting with a thinned 100-foot buffer during a summer discharge of 1.9 cfs.

- Units A, B, and C were cut to within 100 feet of the channel and canopy cover was reduced to 50%.

- During warm summer conditions, the daily range in the temperature of stream water fluctuated up to 10 °C along the 1.5-mile experimental stream reach. For the warmest temperature periods of the years 2000, 2001, and 2002, only a minor change, ± 0.2 °C to 0.5 ± °C, was seen in the average daily water temperature from the control unit C1 to the furthest downstream control unit C4. Overall harvesting in Phases 1 and 2 lowered the minimum water temperature values downstream. The daily minimum water temperature pattern was lower downstream and values decreased up to 0.75 °C after Phases 1 and 2 when compared to pre-harvest Phase 1 data. The monthly maximum water temperature never exceeded 21.1 °C before or after harvest in any location throughout the 1.5-mile experimental stream reach for the three-year study. Downstream cooling in the maximum water temperature occurred in each of the years 2000, 2001, and 2002, and the magnitude of the difference ranged annually between 0.5 °C and 2.3 °C. The annual variation was large, but the variation between the five months where the warmest summer temperature occurred was less than 0.5° C. In general, the trend of the data over the three-year study showed upstream and downstream average, minimum, and maximum water temperature response values becoming more homogenous over time.

- Actual water temperature monitoring in Judd Creek showed only a minor change after harvesting, ranging from $\pm$0.2 ^{o}C to $\pm$0.5 ^{o}C.

Key Findings—Riparian Microclimate:

- Under the timber harvest operations performed for this experiment, the angular canopy cover was reduced 5% mid-stream and 10% within the buffer (WLPZ). After reducing the buffer width to 100 feet, angular canopy cover was 85% mid-stream and at least 82%

within the WLPZ for all three harvest units. The vertical canopy cover following both Phase 1 and Phase 2 harvesting was 50% for the harvest units, which is the lowest allowable minimum canopy cover legally permitted under the California Forest Practice Rules.

- At least a 30% difference between angular and vertical projected canopy cover was measured, and this difference may contribute to confusion over the level of anticipated versus actual measured impacts due to timber harvest operations with riparian zones. The two experimental harvest treatments did not appreciably reduce either the angular or vertical canopy cover within the WLPZ even though 35% of the merchantable overstory tree volume was removed.
- The average and maximum daily air temperature patterns within the riparian zone harvest units (stream bank out to 40 feet) were increased at most up to 0.5 °C due to the adjacent upland experimental harvest treatments. No discernible effect on the minimum daily average air temperature within the riparian zone harvest units was found throughout the entire three-year study.
- No significant change in the average, minimum, or maximum daily relative humidity patterns in the riparian zone of the harvest blocks (stream bank out to 40 feet) were found after the two experimental harvest treatments during the three-year study.
- No change in the average daily soil temperature pattern was found in the riparian zone of the harvest units (stream bank out to 40 feet) after the two experimental harvest treatments during the three-year study.
- The average daily soil moisture in the clearcut units where soil ripping occurred was significantly higher (up to 12%) than any other area in the riparian buffer (WLPZ) for harvest units and all distances from the bank in control blocks. No change in the average daily soil moisture pattern was found in the riparian zone of the harvest units (stream bank out to 40 feet) after the two experimental harvest treatments during the three-year study.

Relevancy:

1. Study was conducted in dry, inland California forests.
2. This is one of the most intensively monitored stream microclimate experiments conducted, and one of only a few with year-round continuous data collection.
3. Relatively narrow riparian buffers are adequate to limit changes in water temperature, and all other measured near-stream microclimate variables, adjacent to harvest units.
4. The Board of Forestry and Fire Protection authorized a CEQA exemption to harvest the riparian buffer to the stream bank, and results were presented to the Monitoring Study Group.

15. Matthews, Graham. April 2003. **A Preliminary Low-Flow Analysis to Assess the Feasibility of Water Drafting in Coastal Mendocino County.** Prepared for Campbell Timberland Management, Fort Bragg, CA. Graham Matthews and Associates, Weaverville, CA.

Objective:

i. To estimate the minimum drainage area required to maintain a minimum average 7-day flow of 2 cfs in coastal Mendocino County, using frequency analysis and regression analysis comparing minimum streamflow to drainage area.

Key Findings:

- Watering is the primary method for required dust suppression on active unpaved logging roads. The water is drawn from waterways (or available artesian sources), but the availability of water is limited as streamflow decreases during the dry season. Water drafting may cause adverse impacts to aquatic resources if flow is reduced to insufficient levels.

- State regulations for temporary water drafting in anadromous salmonid watersheds may require a detailed water drafting plan, including:
    - Minimum instream flows of 2 cfs must be maintained during drafting operations.
    - The diversion rate shall not exceed 10% of the streamflow in the source stream.

- Based on regression analysis, a drainage area of about 74 mi^2 is required to maintain a median $Q7,_{min}$ flow of 2 cfs within a coastal Mendocino County stream; however, uncertainty exists regarding the exact drainage area.

- To meet the two criteria mentioned above, a watershed area of over 74 mi^2 would be needed to maintain a $Q7,_{min}$ of 2.2 cfs, and the diversion rate would be limited to 0.2 cfs (or 90 gpm) in order to maintain 2 cfs of instream flow during diversion operations.

- Typical historical water drafting practices have used a much larger diversion rate (up to 350 gpm) with the standard equipment available. To meet the 10% criteria in the case of a 350 gpm diversion rate would require 7.8 cfs, a $Q7,_{min}$ flow that rarely occurs in coastal Mendocino County, regardless of drainage area.

Relevancy:

1. Many if not most forestland owners cannot satisfy the T&I water drafting standards anywhere on their property, except at the lower end of larger watersheds where water needs are not great.

2. Some forestland owners have spent tens of thousands of dollars monitoring the effects of water drafting for DFG since 2003, and have demonstrated that water drafting can be performed without harm to fish.

16. National Council for Air and Stream Improvement, Inc. (NCASI). 2003. **Influence of Culvert Crossings on Movement of Stream Dwelling Salmonids.** National Council for Air and Stream Improvement, Inc., Research Triangle Park, NC. Technical Bulletin No. 0862.

Objective:

i. To examine the effects of culvert crossings on fish movement over the course of a year using mark-recapture techniques on eight small streams in forested lands of the Cascade Mountains of Washington. Assessments were made of movements of resident and juvenile anadromous salmonids and cottids through culverts and control reaches situated upstream and downstream of road crossings.

Key Findings:

- A total of 5,273 fish (4,409 salmonids and 864 cottids) were captured and marked during the study. Throughout the course of the study, 43% of all marked salmonids were recaptured.
- The majority of the recaptured salmonids (68%) were collected in the same reach in which they had been marked; the remaining 32% moved at least into the adjacent sample reach.
- Over 16% of the recaptured salmonids moved farther than 100 feet in either an upstream or downstream direction. The number of fish detected moving downstream through a control reach (207 fish) was more than double that of upstream detections (102 fish). A total of 52 recaptured fish (51 salmonids, 1 cottid) had moved upstream through a culvert. Thirty cutthroat trout were recaptured over 500 feet upstream of their point of initial capture and marking.
- Upstream fish movement through culverts was comparable to that of the natural control reaches. Immigration of unmarked fish into study reaches was similar both upstream and downstream of study culverts.

Relevancy:

1. The culverts investigated were technically considered barriers under the State of Washington’s culvert installation guidelines. Results indicate that reconsideration of the criteria used to determine the barrier status of culvert crossings during preparation of road maintenance and abandonment plans may be warranted.

17. Olson, Deanna H. and Cynthia Rugger. 2006 submitted. **Initial effects of headwater riparian reserves of four widths with upslope thinning on stream habitats and amphibians.** Forest Science.

Objective:

i. To characterize the response of amphibians and instream habitat conditions to four riparian buffer widths (approximately 20, 49, 230, 476 feet) along headwater streams in young managed Douglas-fir stands, 40-70 years old, with upslope forest thinning which reduced stands from 243 trees per acre (tpa) to 81 tpa.

Key Findings:

- Overall, riparian buffers with upslope moderate thinning (81 tpa) retained the aquatic vertebrate community along channels in the first two years after forest thinning.
- Species occupancy patterns revealed common taxa persisted at sites after thinning and rare species often were detected during only one survey, pre- or post-treatment.
- Altered habitat conditions post-treatment included a decreased pool-riffle ratio, increased stream spatial intermittency, and increased down wood.
- Amphibians were most abundant and diverse in streams and immediately along stream banks, with the amphibian assemblage becoming considerably simpler in the upland forest. Different assemblages were associated with instream perennial and intermittent reaches.
- Analyses (ANOVA) from year-1 and year-2 post-treatment surveys revealed few significant negative effects on species abundances with any buffer width. Post-thinning abundances of bank-dwelling salamanders significantly increased under nine of ten treatment effects.

Relevancy:

1. FPRs aimed at maintaining diverse assemblages of amphibians across the landscape should focus on riparian areas immediately along the banks of small streams.
2. Few significant negative effects on species abundances were detected after timber harvesting with no-entry riparian reserves as narrow as 20 feet wide.
3. Findings suggest that one-size-fits-all riparian buffer widths may not be the most effective regulatory tool for managing riparian and aquatic functions. A mix of riparian reserve widths might be applied in headwaters where biotic values are of concern.

18. Robison, E. George and John Runyon. 2005. **Effects of different riparian management treatments on small headwater streams at the upstream extent of fish use for streams in Western Oregon.** P. 42. In: Oregon Headwaters Research Cooperative. November 2005. Symposium on the Science and Management of Headwater Streams in the Pacific Northwest. Oregon State University, November 17-18, 2005. Oregon Headwaters Research Cooperative, Corvallis, OR.

Objective:

i. To determine the effects of timber harvesting on shade cover, slash loading, channel morphology, and wood loadings in headwater streams.

Key Findings:

- Timber harvesting reduced vegetation cover along small unbuffered streams from 87% to 52%; if 20- to 50-foot-wide buffers were retained on each side of the small streams, vegetation cover was only reduced from 88% to 80%.
- Differences in channel morphology, wood loadings and slash were not detected in reaches with 20- to 50-foot-wide buffers, but increases in slash loading were detected for unbuffered reaches.
- Stream channel morphology, large wood, shade cover and other characteristics were measured for 42 headwater stream reaches (including 15 buffered reaches) in Western Oregon. These stream reaches were purposely chosen to straddle the upstream extent of fish use, which represents a key demarcation point in terms of ecology and forest practice regulation.

Relevancy:

1. FPRs for managing channel morphology, water temperature, and wood loading of small streams should account for the physical limitations of riparian functions along those streams.
2. Small non-fish headwaters have no measurable influence on downstream fish habitat attributes such as channel morphology, wood loadings, and slash.
3. Relatively narrow (20-50 feet wide) riparian buffers retained 80% shade cover over small streams. Unbuffered small streams were 52% shaded, even after complete riparian timber harvesting.

19. Rykken, Jessica and Andrew R. Moldenke. 2005. **Relationships between forest-floor invertebrate distribution, movement, and microclimate under alternative riparian management practices.** P. 45-46. In: Oregon Headwaters Research Cooperative. November 2005. Symposium on the Science and Management of Headwater Streams in the Pacific Northwest. Oregon State University, November 17-18, 2005. Oregon Headwaters Research Cooperative, Corvallis, OR.

Objectives:

i. To describe the ecological significance of headwater stream riparian zones as habitat for forest-floor invertebrate communities.

ii. To assess how alternative management strategies for riparian zones may impact these communities

iii. To compare community composition of forest-floor invertebrates at five distances along 230-foot-long trans-riparian (stream edge to upslope) gradients in mature forests, clearcuts, and across riparian buffers of 100 feet width.

Key Findings:

- Ordination revealed a distinct "riparian" invertebrate community within 3 feet of the stream edge in mature forest treatments, which was strongly related to a cool, humid microclimate.
- The stream appeared to influence microclimate at least 66 feet upslope in the mature forest treatments.
- Invertebrate community composition in buffer treatments was far more similar to that of mature forests than to the community composition of clearcuts, a pattern mirrored by microclimate.
- Microclimatic edge effects were not evident beyond 33 feet into the buffer, suggesting that the stream's cool, humid influence on microclimate may be modifying any warm, drying effects coming in from the forest-clearcut edge.
- While biological edge effects were not clear for invertebrate communities, individual species showed various responses to the buffer edge, depending on their habitat affinities and mobility.
- Invertebrate distributions are strongly associated with microclimate, and riparian buffers of 66-100 feet width provide suitable habitat for many forest species.
- Buffer edges may serve as barriers to dispersal for some forest interior species, or be permeable to invasion by open-habitat species, with possible consequences for long-term population and community dynamics within the buffer.

Relevancy:

1. FPRs that attempt to regulate stream and riparian area microclimates should recognize the physical limitations of their influence over each other. Microclimate effects in this study were limited to 33-66 feet from stream channels within riparian buffers.

20. Sarr, Daniel A., Dennis C. Odion, David E. Hibbs, Jennifer Weikel, Robert E. Gresswell, R. Bruce Bury, Nicole M. Czarnomski, Robert J. Pabst, Jeff Shatford and Andrew R. Moldenke. 2005. **Riparian Zone Forest Management and the Protection of Biodiversity: A Problem Analysis**. National Council for Air and Stream Improvement, Inc. (NCASI), Research Triangle Park, NC. Technical Bulletin No. 0908.

Objective:

i. To evaluate the general effects of forestry practices on biodiversity along streams in the Pacific Northwest and northern California.

Key Findings:

- Biodiversity is expressed as a general concept for species, habitat, and genetic diversity of all groups of organisms. The controlling effects of forestry on biodiversity are:
    - Habitat heterogeneity and retention of pre-disturbance biological legacies (trees, snags, logs, seed and spore banks that can be important to growth of populations of organisms after disturbance) Andras, Kevin, Lee Benda, and Paul Bigelow. 2005.
    - Physiological stress and related resource availability because they may limit the number of species that coexist.
- The report describes the effects of forestry practices on biodiversity along streams in the study area for specific taxonomic groups, and suggests forestry practices that may sustain the selected taxonomic group. Disturbance regimes that are intermediate in influence are predicted to best maintain biodiversity.
- For improving overall biodiversity maintenance, the reports identifies: enhancing habitat heterogeneity, planting multiple crop species, leaving some native trees unharvested to remain through a second rotation, lengthening rotations, earlier thinning schedules, leaving woody debris and snags, creating biological legacies that occur with natural disturbances, and conserving coarse woody debris, and controlling exotic species.

Relevancy:

1. Forest practices in riparian areas that promote intermediate levels of disturbance are best suited to maintaining biodiversity.

21. Shirazi, Mostafa A. and Wayne K. Seim. October 1979. **A stream systems evaluation—An emphasis on spawning habitat for salmonids.** USEPA, Environmental Research Laboratory, Corvallis OR. EPA-600/3-79-109.

Objective:

i. To present a preliminary rationale for conducting a monitoring program with the objective of assessing the level of sedimentation impact both locally in a given stream spawning site as well as more generally for the entire stream that might be impacted by watershed management activities.

Key Findings:

- Simple but reliable procedures are needed to monitor spawning gravels to assess sediment debris that might enter a stream due to forest management practices.
- The ultimate goals of substrate monitoring are to relate watershed processes and forest practices to substrate conditions and to assess the possible impact of accelerated erosion on spawning habitat, both locally in one or more riffles as well as more extensively for an entire stream system.
- The parameters used as impact measures are: (a) changes in the area of spawning gravel, i.e. the change in the available habitat; and (b) changes in the composition of the gravel, i.e. the quality of the habitat. The extent of actual and potential spawning areas for the species of interest can be obtained through visual inspection and areal measurement in the stream reach. The quality of these spawning areas can then be determined by using the sampling procedures previously outlined in this document.
- The mean geometric particle diameter (dg) provides a convenient and theoretically sound parameter that expresses the entire range of the particle distribution and effectively relates particle size to salmonid embryo survival.
  Thus, dg is preferred to percent fines because it is biologically meaningful, sensitive to changes in distribution and, most important, provides a theoretical basis for substrate analysis by considering the entire spectrum of size composition.
- The geology and morphology of watersheds strongly influence substrate composition in the stream systems draining them. For this reason, all spawning gravels in streams unaffected by cultural activities would not be of the highest quality. A hypothetical example demonstrates the areal extent of gravels suitable for salmonid spawning (that expected to yield less than 50% egg survival, as determined by dg) may vary from 8% to 77% among streams.

Relevancy:

1. Forest practices rules based on observations of percent fines in the gravels of receiving waters are less meaningful, sensitive, and indicative of habitat suitability than those using mean geometric particle diameter of gravels.

22. Stillwater Sciences. August 2002. **Bibliography on Percent Fines in Stream Substrate as a Measure of Watershed Condition and Health.** Prepared for Campbell Timber Company, Fort Bragg CA. Stillwater Sciences, Arcata CA.

Objectives:

i. To compile scientific literature addressing the effects of fine sediment in gravel substrate as a measure watershed health.

ii. To focus on the deleterious effects of fine sediment on either salmonid spawning success or macroinvertebrate production.

Key Findings:

- Researchers have used two strategies to determine acceptable levels of fine sediment in spawning gravels: (1) determine the relationship between percent fine sediment and survival of eggs to emergence and set percent fines criteria based on a desired emergence success, or (2) use values for percent fines measured in undisturbed watersheds as targets.

- Field studies are flawed by the inherent difficulties in conducting field experiments on survival to emergence, and field experiments typically are unable to determine accurately the environmental conditions (e.g., percent fines or dissolved oxygen) in the redd egg pocket.

- The relationship of percent fines to emergence success is flawed; percent fines is an inadequate measure of substrate because it does not take into account the total size range of spawning substrate particle sizes that affect embryo survival; it does not provide a clear indication of the survival response to be expected from a particular level of fine sediment under natural conditions.

- Permeability measurements provide a direct measure of the substrate factors that affect incubation conditions and provide a monitoring method that can be implemented more cost effectively than bulk sampling. Egg-to-emergence survival based on gravel permeability can be predicted based on a relationship developed from studies on coho and Chinook salmon.

- Setting a single habitat quality standard based on percent fines is arbitrary. Percent fines within a basin vary significantly due to hydraulic conditions, channel morphology, and basin geology.

Relevancy:

1. Regulatory expectations for controlling sediment delivery to streams needs to account for natural variability and fish capability for developing suitable spawning habitat.

23. Stillwater Sciences. May 2002. **Stream Temperature Indices, Thresholds, and Standards Used to Protect Coho Salmon Habitat: A Review.** Prepared for Campbell Timberland Management, Fort Bragg, CA. Stillwater Sciences, Arcata, CA.

Objective:

i. To lay the foundation for developing a strategy to address the cumulative effects of land management practices on temperature and, by extension, anadromous salmonid populations, particularly coho salmon.

Key Findings:

- Temperature standards are developed to protect fish from both acute temperature effects (e.g., mortality or emigration), and sub-lethal effects, which include temperature-related reductions in growth or other vital functions which may lead to mortality at a later date.

- Acute temperature standards could be based on an annual maximum temperature (i.e., all daily maximum temperatures should be below the threshold), or based on a maximum weekly average temperature (MWAT).

- Sub-lethal temperature standards that ensure sufficient growth could be derived by: (1) assessing the appropriateness of using the MWAT index; (2) developing realistic food availability parameters for use in bioenergetic modeling; and (3) determining the importance of summer growth for juvenile coho salmon in northern California. However, the bioenergetic ecology of juvenile coho salmon needs to be better understood before setting temperature standards to protect rearing juvenile salmonids.

- Even under undisturbed conditions, it is highly likely that northern California coastal streams would have reaches that are too hot for salmonids in summer.

- It is crucial to determine what loss of suitable habitat is acceptable for maintaining and restoring coho salmon populations: (1) the spatial distribution of historical high temperatures and the influence of current and future land management on temperature regimes; (2) the minimum coho salmon population sizes for viability; and (3) the distribution of habitat suitable for different coho salmon life stages (i.e., in some watersheds a small reduction in suitable reaches of stream could eliminate all the habitat for a particular life-stage).

Relevancy:

1. This report discusses potential approaches for developing indices and regulatory temperature standards appropriate for northern California, and how to determine where in a watershed these standards should be applied to protect anadromous salmonid populations in lands actively managed for timber production.

2. It is highly unlikely that forest management practices would negatively impact northern Californian streams rendering them too hot for salmonids in summer.

24. Sullivan, Kathleen, Douglas J. Martin, Richard D. Cardwell, John E. Toll, and Steven Duke. December 2000. **An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria.** Sustainable Ecosystems Institute, Portland, OR.

Objective:

i. To select biologically-based temperature thresholds to protect salmonids.

Findings:

- A risk-based approach that considers both magnitude and duration of temperatures can be used effectively to quantitatively determine biologically-based temperature criteria.
- By applying quantitative methods developed in the report to a wide range of temperature regimes measured in natural streams, it was found that direct mortality from high temperatures was unlikely because temperatures high enough to cause mortality are either never observed, or occur over periods of time too short to cause death.
- Effects on salmonid growth from long-term exposure to ambient temperatures in natural streams were quantitatively assessed using a simplified bioenergetics approach developed in the report. The analysis found that growth predicted from ambient temperatures is somewhat less than the maximum potential growth assuming optimal temperatures in all streams regardless of temperature regime, because no stream experienced optimal temperature all of the time. Generally, the effect of temperature regime on growth was quite low in the range of streams studied, although growth effects were evident in streams with higher temperatures.
- Threshold temperature criteria could be identified for salmonid species based on effects on growth of chronic exposure to temperature during the summer season.

Relevancy:

1. Results suggest that quantitative analysis of growth effects can be determined with reasonably simple methods that can be applied at specific sites or at a regional scale to identify appropriate temperature thresholds.
2. Criteria derived in this manner are similar to those developed by USEPA (1977).

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25. Surfleet, Chris. 2005. **Stream Spawning Gravel Quality (Permeability and Bulk Gravel Samples).** Mendocino Redwood Company, Ukiah, CA.

Objectives:

i. To determine permeability for gravels in redds versus non-redds.

ii. To determine an index of the quality of the spawning habitat for the Garcia, Albion and North Fork Navarro Rivers.

Key Findings:

- Gravel permeability was used to estimate spawning salmon survival to emergence. The following relationship was used to equate the natural log of permeability to fry survival ($r^2 = 0.85$, p<10-7):

$$\text{Survival} = -0.82530 + 0.14882 * \ln \text{permeability}$$

- Although gravel permeability is an index of spawning habitat quality, spawning salmon can improve permeability in gravel where a redd was developed.

- Field measurements and calculations of bulk gravel samples and permeability show that there is highly permeable spawning habitat in the Garcia WAU. Percentage of fine particles less than 0.85 mm is low and the Fredle Indices and Geometric means are moderate to high, which is preferred. Gravels are moderate to highly permeable as well. Redd sites are observed to be more permeable than non-redd stream substrate. This is an expected response to salmonid redd construction. When a redd is constructed fine particles are cleaned from the site likely creating the more porous and thus permeable substrate. Furthermore, the shape and location of a redd possibly creates hydraulic conditions conducive to increased permeability. The percentage of fine particles < 0.85 mm and < 6.3 mm observed in the Garcia WAU are lower inside the redds compared to outside redds, demonstrating how spawning salmonids clean finer substrate particles when building redds.

- Collectively (Garcia, Albion and North Fork Navarro data), the redd versus non-redd data showed redd permeability 53% greater than non-redd permeability.

Relevancy:

1. Spawning habitat quality should not be based simply on gravel permeability because salmon have the ability to clean fine particles from redds.

26. Taratoot, M., P.W. Adams and A.E. Skaugset. 1999. **Assessing effects of timber harvest on riparian zone features and functions for aquatic and wildlife habitat**. Technical Bulletin 775. National Council of the Paper Industry for Air and Stream Improvement, Inc., Research Triangle Park, NC.

Objective:

i. To describe the relative effectiveness of different management prescriptions for streamside management areas and buffers.

Findings:

- Effective and efficient monitoring tools are needed to assess whether streamside management areas are achieving water-quality and wildlife habitat goals. A pilot project was conducted on industrial forest lands to evaluate and refine field methods for assessing riparian functions. Teams monitored stream reaches for in-stream characteristics and functions, riparian area characteristics, and tree features. Measured in-stream characteristics included bankfull width, channel habitat type, dominant substrate size, stream confinement, stream gradient, stream shade, angular canopy density, topographic shading, low cover, and large woody debris. Measured riparian area characteristics included soil exposure, vegetative cover and species, large woody debris (on the ground), canopy cover, slope, tree seedlings, stumps, and snags. Tree inventory measures included tree size and proximity to the stream. The authors developed a protocol to provide useful information for assessing water quality and wildlife functions.

- Suggestions for protocol modifications are provided to improve future monitoring efforts, and for adaptation to inland and coastal forests. Variations between and within riparian forests have important implications for monitoring approaches. The developed protocol, along with suggested modifications, provides investigators with methods to assess the effectiveness of their stream management prescriptions.

Relevancy:

1. The ranges of functions and values among riparian areas vary widely. Some variations across broad geographic regions are expected, but high variabilities also are found between adjacent sites and stream reaches—variability is related to differences in general site characteristics (e.g., stream width, gradient, and riparian slope and aspect).

2. Considering the ranges of conditions, relatively narrow requirements for forest practices within riparian areas to achieve desired benefits could instead yield inconsistent results. Provisions in forest practice regulations that allow managers to implement or develop alternate prescriptions or plans should be maintained or increased. The variable site conditions encountered in this study support the need for alternative riparian forest prescriptions and plans.

27. (a) W.M. Beaty & Associates and CDFG. 2004. **Water temperature and visual habitat assessments during snorkel surveys in South Cow Creek 2002 through 2004, Shasta County, CA.** [Unpublished data.] W.M. Beaty & Associates, Redding, CA and California Department of Fish and Game, Redding, CA.

    (b) UC Cooperative Extension. 2004. **Temperature data and fish counts in South Cow Creek 2002-2004.** [Unpublished data.] UC Cooperative Extension, Redding, CA.

Objective:

i. To examine the effect of timber harvesting on cold water fish and fish habitat.

Key Findings:

- Supporting documentation includes Region 1 CDFG memo to files indicating "habitat is suitable for steelhead spawning and rearing" and "gravel is very clean."
- Temperature and habitat conditions are favorable for cold water fish species.
- For additional information, contact Larry Forero, UC Cooperative Extension, Redding, CA.

Relevancy:

1. These field investigations and reports by state agencies document that careful timber harvesting in riparian zones can be performed without negative impacts on cold water fish and fish habitat.

28. Welsh, Hartwell H., Jr., Garth R. Hodgson, Bret C. Harvey, and Maureen E. Roch. 2001. **Distribution of Juvenile Coho Salmon in Relation to Water Temperatures in Tributaries of the Mattole River, California.** North American Journal of Fisheries Management 21:464-470.

Objective:

i. To define the upper thermal tolerance of coho salmon using the relationship between fish presence and the summer temperature regime in the Mattole River.

Key Findings:

- MWMT and MWAT were used to describe the temperature regime and provided good-fitting models of the presence or absence of coho salmon, and both correctly determined the presence or absence in 18 of 21 streams, given the previous probability of a 50% likelihood of coho salmon presence.

- Temperature regimes in the warmest tributaries containing juvenile coho salmon had MWMT of 18.0°C or less or MWAT of 16.7°C or less; conversely, all of the streams where MWMT was less than 16.3°C or MWAT was less than 14.5°C contained juvenile coho salmon. It is unlikely that streams with temperatures above these thresholds provide appreciable rearing habitat for coho salmon in the absence of extremely high food availability, which might mitigate elevated metabolic rates of fish in these streams. Temperature-dependent competition between species may limit the thermal tolerance of coho salmon in natural streams.

- Although these temperatures imply an upper limit for coho salmon in the Mattole, they cannot serve as goals or targets for particular streams without consideration of historical thermal regimes in those streams in the absence of management activities. Natural spatio-temporal variation in watershed processes and vegetation probably yielded many streams too warm for coho salmon.

- Juvenile coho salmon should not be used as a surrogate species for tailed frog or southern torrent salamander, which may require cooler thermal regimes than coho salmon and commonly occupy smaller channels and springs in cooler upstream habitats inaccessible to fish. In the Mattole reaches containing tailed frogs, MWMT averaged 14.6°C, and MWAT averaged 13.8°C. In the reaches containing southern torrent salamanders, MWMT averaged 14.5°C, and MWAT averaged 13.8°C. Summer stream temperature data from across the southern range of both amphibian species indicated that the maximum temperature at which they occurred was 15°C.

Relevancy:

1. The thermal regimes of Mattole River tributaries supporting coho salmon appear to conflict with published information on the thermal tolerances of coho salmon.

2. Forest practices rules need to be based on realistic natural and historical temperature regimes, and tolerances of species requiring cold water, including coho salmon, tailed frog, and southern torrent salamander.

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29. Wilzbach, Margaret A., Bret C. Harvey, Jason L. White, and Rodney J. Nakamoto. 2005. **Effects of riparian canopy opening and salmon carcass addition on the abundance and growth of resident salmonids.** Can. J. Fish. Aquat. Sci. 62: 58–67.

Objective:

i. To study the concurrent effects of riparian canopy opening and salmon carcass addition on salmonid biomass, density and growth rates in small streams over 2 years.

Key Findings:

- After removal of red alder and other hardwoods along both banks to increase incident radiation, total density and biomass of cutthroat trout and rainbow trout from pretreatment levels responded positively to canopy removal.
- Salmon carcass addition had no detectable effect on total density and biomass of cutthroat trout and rainbow trout.
- Differences in specific growth rates of the fish between open and closed canopy reaches were greater in sites without carcasses than in sites with carcasses.
- In light-limited settings where temperature gains associated with canopy opening are not problematic for aquatic resources, gains in salmonid production might be achieved by selective cutting of riparian hardwoods.
- The effect of a given temperature increase on salmonid production depends on interactions among growth, food consumption, temperature, and other factors; modest temperature increases need not reduce production.
- Carcass introductions may fail to enhance salmonid production in settings where light limits primary production or when other factors operate that prevent successful use of carcasses by salmonids.
- Water temperature increases are not problematic until they approach a level at which they become stressful for the organisms one is hoping to maintain.

Relevancy:

1. Gains in salmonid production might be achieved by selective cutting of riparian alder or other hardwoods, if other habitat requirements are met.
2. The importance of light in affecting food supply for fish has been generally undervalued by management agencies who rank riparian vegetation that provides as much shade as possible “better” in habitat evaluations than vegetation that provides less shade.

30. Wright, David W. October 2004. **Report on Water Drafting Tests for the Summer of 2003 on the Hawthorne Timber Company Ownership.** Hawthorne Timber Company, LLC, Fort Bragg, CA.

Objectives:

i. To quantify hydrologic effects of summer water drafting on forest streams.

ii. To determine if water drafting during summer low flows causes a negative response from aquatic biota.

Key Findings:

- The major conclusions of summer water drafting tests were:
  - Drafting did not increase water temperature.
  - Pool tail crests (the streambed elevation at the outlet of the water drafting pool) did not dewater.
  - Recovery time at all sites ranged from 2 to 19 minutes; mean recovery time occurred within 7 minutes.
  - No stressors to aquatic biota observed.
- At some sites, depth and velocity decreased as flow diminished, as would be expected; at other sites, the relationship was not as clear, particularly regarding the velocity response.
- Geologic conditions that store a considerable volume of water offset the effects of drafting by producing a greater capacity for groundwater recharge.
- Channel depth and velocity are highly dependent on localized channel morphology and environmental conditions.

Relevancy:

1. Channel depth and velocity are dependent on a multitude of site-specific variables, and are too locationally sensitive to be applied universally as regulatory indicators of the effects of water drafting on downstream biota.
2. Regulatory thresholds that combine discharge, depth, and velocity variables do effectively limit water diversion under low flow conditions. Unfortunately, the measurement of these variables is expensive and logistically challenging. A more practical regulatory tool is to prohibit the dewatering of downstream habitat below a specified height.
3. Set the source flow threshold at 1 cfs, and the minimum depth at 0.2 feet above the tail crest height of the drafting pool.

31. Wright, David W. 2006. **Case Study: McNeil Sampling in North Coast Watersheds**. Campbell Timberland Management, Fort Bragg, CA.

Objective:

i. To explore variation among the reporting of fine sediment values and how the values can be transformed by the application of the correction factors.

Key Findings:

- The report considers correction factors that may be applied to the McNeil or Valentine protocols for spawning gravel assessment during the summer non-spawning season using the wet sieve method, and explores possible corrections that could be applied in order to gauge STE.
- Initially, the spawning gravel sample must be corrected for the seasonal differential, then corrected for the differential between spawned and un-spawned substrate, and finally for the measuring bias inherent in the wet sieve method. If all three corrections were applied, the stated results would be considerably lower than uncorrected values.
- The Kondolf Correction (.67X) is the correction factor to allow for the observed differential in fine sediment between spawned and unspawned substrate. The "winnowing" correctional coefficient was suggested by Kondolf (2000).
- The Shirazi Correction (.87X) is the mean of the correction factors established by Sharazi to account for the differential between wet and dry sieved samples (Sharazi 1978).
- The Campbell Timberland Management (CTM) Correction (.74X) is the correction to account for the differential in empirical values between summer and winter fines at established sampling locations (CTM unpublished).

Relevancy:

1. The threshold for impairment determination of less than 14% fine sediment in stream substrate adopted by the Regional Water Quality Control Board is a mean value in a range observed by various researchers investigating the effects of fine sediment within redds on salmonid embryo survival.
2. Problems with estimating fine sediment in spawning gravel, reflected by the differing value correction procedures, must be addressed if this method of gravel assessment is used as a water quality single statistic target.
3. Special consideration is required to ensure samples are collected in accordance with a statistically sound sampling strategy that effectively characterizes gravel quality within a watershed over time.

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32. Zwieniecki, M. and M. Newton. 1999. **Influence of streamside cover and stream features on temperature trends in forested streams in Oregon.** Western Journal of Applied Forestry 14(2):106-113.

Objective:

i. To assess whether streamside cover of streams and various stream features explain the patterns of temperature fluctuation observed.

Key Findings:

- Timber harvesting along low elevation western Oregon streams with riparian buffers (8.6-30.5 m, or 28-100 feet wide) was followed by little direct local effect on water temperature.
- A study of 14 streams demonstrated that all have a tendency to warm with downstream direction even under full forest cover.
- After the natural warming trend of the stream water was accounted for, water at slightly higher temperatures within the buffered clearcut zones cooled to the trend line of temperature by 150 m (492 feet) downstream.

Relevancy:

1. Streams naturally get warmer with decreasing elevation. A warming trend line (with decreasing elevation) can be described as the norm for fully covered forests. This temperature trend should be used to estimate the net temperature effect associated with management practices.

Control of Erosion and Effects of Sediment Delivery

33. Andras, Kevin, Lee Benda, and Paul Bigelow. 2005. **Erosion Rates in the Ten Mile River Basin, Northern California Using Cosmogenic Isotopes.** Lee Benda and Associates, Inc., Mt. Shasta, CA.

Objective:

i. To estimate natural background erosion rates in north coastal California watersheds using cosmogenic isotopes.

Key Findings:

- Cosmogenic isotopes were used to analyze long-term erosion rates at ten sites in two subbasins located in the Ten Mile watershed in the northern California Coast Range. Catchment-averaged bedrock erosion rates in Bear Haven and Redwood Creek subbasins were 0.069-0.136 mm/yr over time intervals of 4,300 years to 8,600 years. Corresponding average basin sediment yields were 186-366 t/km^2/yr. The cosmogenically-derived long-term erosion rates are approximately 240% higher than the short-term, decadal erosion rate estimated by EPA for the Ten Mile watershed.
- The higher erosion rates associated with longer periods of time (i.e., millennial scales targeted by cosmogenic studies) occur because longer intervals are more likely to record extreme erosive events triggered by large storms, fires, floods, and earthquakes compared to shorter intervals.
- Higher long-term erosion rates were also documented in Caspar Creek in northern coastal California and in the Little Lost Man basin in the Redwood National Park, although the average discrepancy was approximately 200%. However, millennial and decadal erosion rates were similar at Panther Creek and Redwood Creek at Orick and decadal erosion rates were higher than the millennial rates in Coyote Creek by a factor of 3.6. The latter discrepancy may be due to accelerated erosion due to land use, particularly early forestry practices.
- The disparity between short and long term erosion rates indicates the overwhelming importance of extreme erosion events in some landscapes.

Relevancy:

1. Regulatory agencies contrast natural erosion rates with estimated increases in erosion due to timber harvesting to impose constraints on forest practices; but, sediment budgets developed by agencies determine erosion rates over relatively short time periods—i.e., several decades—a time period often constrained by the availability of aerial photographs and historical land use records. Forest practices rules should reflect the long-term context of natural erosion rates for managing water quality in forested watersheds.

34. Benda, Lee E., N. Leroy Poff, Christina Tague, Margaret A. Palmer, James Pizzuto, Scott Cooper, Emily Stanley, and Glenn Moglen. December 2002. **How to avoid train wrecks when using science in environmental problem solving.** BioScience 52(12): 1127-1136.

Objectives:

i. To make the process of conducting successful interdisciplinary collaborations and constructing solvable problems more transparent, efficient, and rigorous.

ii. To illustrate the analysis of disciplinary knowledge structures using the general topic of land use impacts on riverine ecosystems.

Key Findings:

- The success of interdisciplinary collaborations among scientists can be increased by adopting a formal methodology that considers the structure of knowledge in cooperating disciplines. The structure of knowledge can comprise of five categories of information: (1) disciplinary history and attendant forms of available scientific knowledge; (2) spatial and temporal scales at which that knowledge applies; (3) precision (i.e., qualitative versus quantitative nature of understanding across different scales); (4) accuracy of predictions; and (5) availability of data to construct, calibrate, and test predictive models.

- There are dangers if science teams, or mixed science–policy teams, ignore the knowledge structure of individual disciplines. For instance, where collaborative teams fail to recognize that contributing disciplines approach problem solving with differing forms of knowledge, additional studies may be commissioned with little chance of success, delaying policy and management decisions. Similarly, science can be used as a "litmus test" in which a question (typically a quantitative one) is forced upon a science team or policy group, with no expectation of a precise answer, to justify a particular ideological doctrine.

- Conducting an epistemological analysis of the scientific disciplines involved with environmental problems can help establish realistic expectations about the role of science, the adequacy of information, and the effectiveness of management policies in dealing with particular problems. By recognizing limits and identifying commensurate scales of analysis, scientists can help guide and direct debates surrounding the appropriate use of scientific knowledge in environmental risk assessment and in setting management policy.

- The comparative analysis of knowledge structures reveals that the scale and precision of analysis in hydrology and geomorphology do not match well with those of riverine ecology. Consequently, ecological responses to land use change are often couched in qualitative terms. For example, hydrologists can make relatively accurate predictions of changing peak flows in a watershed using new, spatially distributed models. Using this information, geomorphologists can make only relatively inaccurate predictions of sediment transport and cannot say anything definitive regarding bed scour or changes in channel form. As a result, ecologists may say that certain taxa are at risk, but quantitatively defining that risk in terms of changes in abundance of individual species or the change in community diversity is not generally feasible.

- Typical watershed analysis involving surface water hydrology, geomorphology, and riverine ecology uses an assessment procedure that simply omits biological consequences. Therefore, land use impacts are evaluated as effects on physical habitats under the simplifying assumption that physical habitat conditions are tightly coupled to biological responses.

Relevancy:

1. Formally recognizing the absence of quantitative scientific knowledge or the low precision of scientific understanding can impart legitimacy to questions that generate qualitative and contextual answers.

2. However, pivotal forest practices rules should not be based on questions to science teams requiring knowledge that is not available, or that will not be forthcoming in the near future.

35. Brandow, C.A., P.H. Cafferata, and J.R. Munn. 2006. **Modified Completion Report monitoring program: monitoring results from 2001 through 2004.** Monitoring Study Group Draft Final Report prepared for the California State Board of Forestry and Fire Protection. Sacramento, CA. 75 p.

Objective:

i. To review completed timber harvesting plans and assess the implementation and effectiveness of the California Forest Practice Rules on WLPZs (percent total canopy, erosion features), roads, and watercourse crossings.

Key Findings:

- The rate of compliance with the FPRs designed to protect water quality and aquatic habitat is generally high.
- The FPRs are highly effective in preventing erosion, sedimentation and sediment transport to channels when properly implemented.
- In most cases, Watercourse and Lake Protection Zone (WLPZ) canopy and groundcover exceeded Forest Practice Rule (FPR) standards.
- For Class I and Class II WLPZs, average total percent canopy was 84% for the Coast area (Region 1), 68% for the Inland North area (Region 2) and 73% for the Inland South area (Region 4). With rare exceptions, WLPZ groundcover exceeds 70%, patches of bare soil in WLPZs exceeding the FPR standards are rare, and erosion features within WLPZs related to current operations are uncommon.
- In most cases, actual WLPZ widths were found to meet or exceed FPR standards and/or widths prescribed in the applicable THP.
- When properly implemented, road-related FPRs were found to be highly effective in preventing erosion, sedimentation and sediment transport to channels. Overall implementation of road-related rules was found to meet or exceed required standards 82% of the time, was marginally acceptable 14% of the time, and departed from the FPRs 4% of the time.
- Road-related rules most frequently cited for poor implementation were waterbreak spacing and the size, number and location of drainage structures.
- This low rate of non-compliance is important because erosion and sedimentation was found to be much more likely at road-related features where the FPRs are not properly implemented. Additionally, erosion, sedimentation and sediment transport is much more likely at road-related features where there was a departure from the applicable FPRs.
- For watercourse crossings, overall, 64% had acceptable implementation of all applicable FPRs, while 19% had at least one feature with marginally acceptable implementation and 17% had at least one departure from the FPRs. Common deficiencies included diversion potential, fill slope erosion, culvert plugging, and scour at the outlet.
- Results are consistent with those reported by the Hillslope Monitoring Program (Cafferata and Munn 2002).

Relevancy:

1. Results show when forest practice rules are implemented they are very effect at maintaining high standard of environmental quality.

2. Sediment delivery to watercourses can be reduced most appropriately and significantly through improved road drainage structure and watercourse crossing structure design, construction, and maintenance along forest roads.

3. Results mostly point to a need for better rule implementation, not stricter rules. Several recommendations are provided to improve implementation, mainly related to training needs. Additionally, use of a road management plan is recommended.

36. Cafferata, Peter H. and John R. Munn. December 2002. **Hillslope Monitoring Program: Monitoring Results from 1996 through 2001.** Monitoring Study Group Final Report prepared for the California State Board of Forestry and Fire Protection. Sacramento, CA. 114 p.

Objectives:

i. To gather implementation and effectiveness data to determine if the California Forest Practice Rules are adequately protecting water quality.

ii. Data were collected from selected areas of THPs and NTMPs with the highest risk to water quality. Fifty completed THPs that over-wintered 1-4 years were sampled annually. Detailed information collection included: (1) randomly located road, skid trail, and watercourse and lake protection zone (WLPZ) segments, as well as randomly located landings and watercourse crossings; and (2) large erosion events (e.g., mass wasting features) where they are encountered. Monitoring was performed by highly qualified independent contractors who acted as third party auditors by collecting field data for an extensive database.

Key Findings:

- The Hillslope Monitoring Program, from 1996 through 2001, showed that implementation rates of the FPRs related to water quality are high (averaging 94%) and that individual practices required by the rules are effective in preventing hillslope erosion when properly implemented. At erosion sites, implementation of applicable rules was nearly always less than required by the FPRs.

- Roads and their associated crossings have the greatest potential for sediment delivery to watercourses. Nearly half of the observed watercourse crossings had at least one implementation problem. New culverted crossings installed under the THP had a significantly lower rate of implementation problems compared to pre-plan culverted crossings. Common culvert problems included culvert plugging, stream diversion potential, fill slope erosion, scour at the outlet, and ineffective road surface cutoff waterbreaks.

- Landings and skid trails did not produce substantial impacts to water quality.

- Watercourse protection zones were found to retain high levels of post-harvest canopy and surface cover, and to prevent harvesting-related erosion. Mean total canopy exceeded FPR requirements in all three Forest Practice Districts and was approximately 80 percent in the Coast Forest Practice District for both Class I and II watercourses. Surface cover exceeded 75 percent for all watercourse types in the three districts. WLPZ width requirements generally were met, with major rule departures recorded only about one percent of the time. The frequency of erosion events related to current operations in watercourse protection zones was very low for Class I, II, and III watercourses.

- Study results are applicable to the performance of FPRs prior to July 1, 2000.

Relevancy:

1. Sediment delivery to watercourses can be reduced most appropriately and significantly through improved road drainage structure and watercourse crossing structure design, construction, and maintenance along forest roads.

2. Results mostly point to a need for better rule implementation, not stricter rules. Several recommendations are provided to improve implementation, mainly related to training needs. Additionally, use of a road management plan is recommended.

37. McBain & Trush. April 2000. **Spawning Gravel Composition and Permeability within the Garcia River Watershed, CA: Final Report.** Prepared for Mendocino County Resource Conservation District, Ukiah, CA. McBain & Trush, Arcata, CA.

Objectives:

i. To establish baseline substrate composition and permeability conditions for long-term trend monitoring in the Garcia River watershed.

ii. To assess the relationship (correlation) between substrate composition and permeability, and the general utility of these methods for assessing the condition of salmonid spawning substrates.

Key Findings:

- Monitoring techniques are needed that quantify salmonid spawning habitat for spawning and incubation success, and that describe the variability in the spawning habitat conditions with specified precision. To gather substrate composition data with sufficient precision to characterize spawning gravel quality of an entire stream reach requires an enormously expensive sampling effort. E.g., substrate composition data for 10 tributaries to the Garcia River (20 samples/tributary) would require expenditure of at least $10,000. per tributary.

- The permeability methods evaluated as part of this study show the potential to define the variability in spawning gravel quality with better resolution and at lower cost than substrate composition analysis, but the relationship between permeability and salmonid egg survival is less well known. Until this relationship is better defined, permeability should only be considered an index of gravel quality, and predictions of salmonid reproductive success are tentative.

- This study has: (1) established baseline monitoring data for spawning gravel quality of ten tributaries to the Garcia River that support listed salmonid species; (2) shown a weak correlation between particle size fractions of substrate samples collected within the Garcia River watershed, and permeability measurements taken within the substrate sample; (3) provided evidence that permeability methods may better describe the condition of salmonid spawning gravels than substrate composition analysis, but a stronger relationship is needed between permeability and salmonid egg survival; and (4) provided methods for estimating the sample size needed to achieve specified levels of precision in the data, for either substrate composition analysis or permeability.

Relevancy:

1. Characterization of spawning gravel quality with sufficient precision for an entire stream reach requires an enormous sampling effort, perhaps beyond the capabilities and budgets of resource agencies, organizations, and private companies. Clearly, better methods are needed.

2. Permeability methods evaluated as part of this study show the potential to define the variability in spawning gravel quality with better resolution and at lower cost than substrate composition analysis.

38. Redwood Creek Landowners Association. 2000. **A study in change: Redwood Creek and salmon.** Steve Mader and Ann Hovland [eds.]. CH2M HILL, Inc., Portland, OR.

Objectives:

i. To examine the agents of ecological change—floods, earthquakes, landslides, fires, land uses, and the influence of the ocean—and the consequences of these changes on the physical environment and aquatic resources within the Redwood Creek basin.

ii. To provide a better understanding of issues influencing regulatory treatment of Redwood Creek regarding water quality, Section 303(d), controlling nonpoint sediment sources, and specially-designated fish.

Key Findings:

- For many years, man rather than nature was suspected to be the greatest source of suspended sediment loading of Redwood Creek. After much study, geologists determined that most sources of erosion in the Redwood Creek basin produced minor or inconclusive amounts, but it became clear that the largest amount of human-caused erosion was at the point where roads crossed small streams.
- Over the past 25 years, the amount of fine sediment in Redwood Creek has become generally, though inconsistently, reduced, due in part to fewer intense storms than during previous periods of history.
- Numerous studies have concluded that: (1) streams draining timber harvested areas with roads temporarily contain higher amounts of fine sediment after logging when compared with "control" streams, (2) temporary increases in fine sediment have virtually no short or long-term adverse effects on aquatic organisms, and (3) salmon are physiologically and behaviorally adapted to living in a dynamic, sediment-rich environment.
- The number of juvenile salmonids present in Redwood Creek in the summer has not been correlated significantly with the volume of fine sediment in the streambed. Furthermore, the later life stages of anadromous fish seem to show no discernible changes even though sediment levels affecting salmonid reproduction may vary.

Relevancy:

1. Land management policies for Redwood Creek must take into consideration the cyclical agents of change when addressing issues related to salmon and trout populations and freshwater aquatic habitats.
2. The regulatory climate must take into consideration natural histories and ecological potentials. Only with realistic expectations for sediment loading capacities and water quality can compatible land management activities be implemented with appropriate flexibility.

39. Rice, Raymond M. October 1999. **Erosion on Logging Roads in Redwood Creek, Northwestern California.** Journal of the American Water Resources Association 35(5):1171-1182. [AWRA Paper Number 98043]

Objective:

i. To quantify the erosion caused by logging roads in the Redwood Creek watershed.

Key Finding:

- The amount of sediment reaching watercourses from forest roads in the intensively-managed Redwood Creek watershed, which contains one of the most highly erosive stream systems on the North Coast, was significantly less than 1 percent of the average natural background rate of suspended sediment transport.

Relevancy:

1. The interim T&I Watershed rules do not appear to reflect a large and growing body of forest practices monitoring reports that generally indicate the appropriateness of rule flexibility for addressing local site conditions and the fact that current CFPRs were doing a good job in conserving ecological values and steadily improving environmental conditions.

2. *Erosion on logging roads in Redwood Creek, Northwestern California* (Rice 1999) was released subsequent to the SRP Report that led to the interim FPRs.

40. Stillwater Sciences. May 1997. **A review of coho salmon life history to assess potential limiting factors and the implications of historical removal of large woody debris in coastal Mendocino County.** Prepared for Louisiana-Pacific Corporation, Wildlife and Fisheries Science Group, Trinidad, CA. Stillwater Sciences, Berkeley, CA.

Objectives:

i. To review coho salmon life history.

ii. To assess potential limiting factors of timber harvesting and the implications of historical removal of large woody debris in coastal Mendocino County.

Key Findings:

- The fisheries resource of particular interest in coastal areas of Mendocino County, California is coho salmon because of its importance for sport and commercial harvest, and its status as a federally listed threatened species. The suitability of coastal streams for coho salmon can be heavily influenced by forest practices because such actions may cause changes in fine sediment loads, stream cover conditions, and channel morphology that can have a pronounced effect on the quality of coho salmon habitat. Actions taken to protect, enhance, and monitor habitat conditions for coho are assumed to provide benefits to other resident and anadromous species as well.

- This review summarizes knowledge about salmon spawning, incubation and emergence, rearing, outmigration, and ocean life, as they are influenced by conditions of the aquatic environment.

- A special section of the review is devoted to the relationship of large woody debris to coho salmon production, and the historical effects of debris clearing from streams.

Relevancy:

1. This technical report on coho salmon was designed to develop Sustained Yield Plans (SYP) and a Habitat Conservation Plan (HCP) for timberlands in coastal Mendocino and Humboldt counties.

2. The review provides excellent summaries of the effects of logging and road construction on coho salmon, management considerations the streamside or riparian zone, and stream habitat enhancement and restoration opportunities.

41. Stillwater Sciences. March 2002**. Stream Temperature Indices, Thresholds, and Standards Used to Protect Coho Salmon Habitat: A Review.** Prepared for Campbell Timberland Management, Fort Bragg, CA. Stillwater Sciences, Arcata, CA.

Objective:

i. To recommend issues to be addressed in the short term to develop temperature water quality standards protective of fish in northern California.

Key Findings:

- To increase the applicability of the Hines and Ambrose (2000) and Welsh et al. (2001) approach, a short, focused field study that controls for stream size and habitat characteristics could be used to assess the degree to which application of a MWAT threshold can protect juvenile coho salmon from temperatures that cause direct mortality or emigration.
- To address some of the concerns in the Sullivan et al. (2000) approach, available data could be analyzed to address the relationship between MWAT and long-term, sub-lethal temperature patterns in northern California, and to compare temperature characteristics in Washington vs. northern California streams.
- It is crucial to determine the bioenergetic ecology of juvenile coho in northern California, including the seasonal variation in food availability and seasonal growth patterns.
- The spatial application of temperature standards within a basin should be addressed using a modeling approach combined with a scientific analysis of the degree to which stream shading can be reduced from historical conditions while still fully protecting coho populations.
- Some issues for stream temperature standards can be readily answered with available data.

Relevancy:

1. It would be appropriate to use a collaborative approach including the Board and other experts to address issues of uncertainty to ensure biologically relevant protections for fish in northern California. A list of issues is provided.
2. It is possible that a regulatory approach based on Sullivan et al. (2000) could be implemented by addressing only its most crucial uncertainties.
3. Any regulatory approach should consider the spatial context of applying standards in a basin.

42. Valentine, Bradley E. January 4, 1995. **Stream Substrate Quality for Salmonids: Guidelines for Sampling, Processing, and Analysis.** [Draft]. California Department of Forestry and Fire Protection, Coast Cascade Regional Office, Santa Rosa, CA.

Objective:

i. To provide guidelines to parties requested by the state (through review team or other functions)—or who chose to do so on their own volition—to evaluate or monitor the stream beds on lands they manage with a stream-bed, grab-sample approach. The guidance generally follows that of Klamt (1976).

Key Findings:

- Excessive erosion and land-sliding can limit fish populations—most notably anadromous salmonids—at several times in the species' life cycles. Among the impacts are: (1) in-filling of pools which reduce the volume and quality of living space for over-summering parr, and (2) reduction in average size of stream substrate, which reduces spawning success and restricts the fishes' food base. Research has focused on the relationship between substrate particle size and egg-to-fry survival to emergence.

- For percent fines, thresholds of concern fall most commonly around 20%. The relationship between the survival to emergence of several salmonid species can be portrayed by standards, such as the geometric mean, the Fredle Index, or a graphical depiction based on the percent of a sample finer than two size intervals.

- Because sedimentation of fines is less of a problem as stream gradient increases, bulk sampling of the substrate should be limited to locations where both gross and site gradient are less than 3%. Streams to be sampled should be restricted to those that are 5th order or smaller, as ordered using bluelines on USGS quads. To describe entire channel conditions, a random sampling scheme should be developed in which all of the bankfull channel is subject to sampling. If the sampling universe is salmonid redds, then sampling should be conducted in randomly sampled redds after young have emerged.

- Most standards are based on spawning environments. Therefore, any assessment of stream condition must recognize the difference between its sampling location protocol and the standards.

  - Sampling from redds after emergence is the most applicable use of the standards.

  - Using the standards to judge conditions when samples are collected from the pool/riffle juncture will provide a "worse case" assessment. The survival to emergence value from samples when compared to the standards will be a conservative estimate of survival.

  - When sampling is fully randomized across and along the stream channel and is unrelated to spawning sites, the criteria provided above are not applicable. While coarser is better, the results of such a sampling scheme have not been related by research with any parameters of fish populations.

Relevancy:

1. Two parameters of the spawning gravel substrate are important: condition and trend. The procedures provided in these guidelines, applied at a single time, enable reviewers

to assess condition. Current condition can be variable due to localized natural geologic events, historic land uses, current land uses, and short- (1-5 year) to long-term (decade ±) climate conditions. Relative to forest practices decisions, interpretation of the significance of "condition" is complicated by this inherent variability. Even short-term conditions may be critical when the population of a species that is sensitive to substrate character is extremely low. However, generally trend is of greater significance than a snapshot of current condition.

Cumulative Effects Analysis

43. Barber, T. and A. Birkas. 2005. **Garcia River Trend and Effectiveness Monitoring: Spawning Gravel Quality and Winter Water Clarity in Water Years 2004 and 2005, Mendocino County, California.** Final Report prepared for the Mendocino County Resource Conservation District. Ukiah, CA. 70 p.

Objectives:

i. To determine if sediment and turbidity conditions are improving for anadromous salmonids in sub-watersheds in the Garcia River watershed.

ii. To use continuous turbidity measurement to locate sediment sources and determine both the total and consecutive days turbidity is sustained over biologically-related turbidity thresholds. Five continuous recording turbidity monitoring stations were operated in water years 2004 and 2005.

Key Findings:

- Gravel redds were significantly more permeable at Pardaloe Creek, and possibly more permeable at Inman Creek and the South Fork Garcia River (not statistically significant). Fewer fines in spawnable gravels were found at Pardaloe Creek and South Fork in 2004 than in 1999, but these improvements were not significant statistically.
- In water year 2004, one subwatershed with recent road restoration work (South Fork) and at another subwatershed having both the lowest timber harvest intensity and the lowest road density (Pardaloe) had the lowest total numbers of hours with turbidity exceeding a threshold of 30 NTUs.
- Of the five tributaries sampled in water year 2005, the South Fork tributary watershed exhibited both the lowest peak turbidity and the lowest chronic turbidity using the 30 NTU threshold. In general, the other streams had no restoration work and had moderate to high timber harvest intensities, and these basins exhibited greater peak and chronic turbidity.
- Road restoration work and past timber harvest intensity and/or roading may explain these differences, but insufficient data are available to determine whether these differences are significant.
- Contact: Teri Jo Barber, Ridge to River (707) 937-0120.

Relevancy:

1. Provides trend monitoring data for Garcia River tributaries.

44. Cafferata, Peter H. and John R. Munn. October 2004. **THP No. 1-03-185 SON; Hydrologic Review of Heat Source Model Study.** California Resources Agency, Department of Forestry and Fire Protection, Sacramento, CA.

Objective:

i. To review the Heat Source model work submitted by Gualala Redwoods, Inc. for THP 1-03-185 SON, located along the South Fork of the Gualala River.

Key Findings:

- The Heat Source model is probably the best model currently available for California forestlands and varying riparian buffer strip harvest scenarios.
- A worst-case (or near worst-case) scenario was modeled for low discharge because 2001 was a year of low water discharge.
- Based on channel configuration, size of riparian trees, stream orientation, wetted summer width of channel, inflow from tributaries along the ~6-mile reach, and other parameters, it was not surprising that the model predicted virtually no change in downstream water temperature with very little WLPZ harvesting.
- The results reported by Western Watershed Analysts (Schult and McGreer 2004) for the South Fork Gualala River are reasonable and can be relied upon.

Relevancy:

1. Riparian timber harvest prescriptions for the South Fork Gualala River, in accordance with the California FPRs and the Iris THP, would not impact water temperatures.
2. Modeling revealed no discernible differences between the pre-harvest and post-harvest stream temperatures under the FPRs, as evidenced by essentially identical temperature points for pre-harvest and post-harvest.

45. CDFG. 2000, 2002, and 2003. **Bioassessment Reference Condition Project.** Sacramento River Watershed Program, California Department of Fish and Game, Sacramento, CA.

Objective:

i. To conduct a paired watershed study using South Cow Creek as a reference stream, indicating best available condition for fish.

Key Findings:

- Prolonged timber harvesting has occurred in the South Cow Creek watershed.
- South Cow Creek is designated as threatened and impaired.
- Results of the Bioassessment Reference Condition Project for South Cow Creek indicate all sensitive invertebrate taxa are present and habitat condition is good to excellent.
- South Cow Creek was selected by CDFG as a reference stream, indicating best available condition for use in a paired watershed study.

Relevancy:

1. Sensitive species and good to excellent habitat quality are compatible with timber harvesting practices under prior FPRs in the South Cow Creek watershed.
2. Threatened and impaired designations for watersheds such as South Cow Creek need to be reconsidered in light of the fact that they exhibit exemplary ecological qualities to the extent they are used by CDFG as reference streams.

46. Dietterick, B. 2003. **ARI Final Report for Long-Term Evaluation of Suspended Sediment Exiting a Coastal Mountain Stream Following Selection Timber Harvesting Activities.** California Polytechnic State University, San Luis Obispo, CA. http://ari.calpoly.edu/images/46670%20Dietterick%20Final.doc

Objectives:

i. To evaluate the effects of selective timber harvesting in the Santa Cruz Mountains of California to determine if current practices adequately protect watersheds from adverse sediment-related impacts, using four continuous recording monitoring stations in two forks of Little Creek watershed.

ii. The project will document watershed conditions and suspended sediment export before, during, and after single-tree and small group selection harvests.

Key Findings:

- High inter- and intra-station variability warrant intensive sampling for upstream/downstream strategies where multiple sources of sediment delivery exist.
- Contact: Dr. Brian Dietterick, Natural Res. Mgt. Dept., Cal Poly, San Luis Obispo, CA. (805) 756-6155.

Relevancy:

1. The study provides information about the effectiveness of FPRs at the Little Creek watershed.
2. This information will assist in determining the effectiveness of the current California Forest Practice Rules in Santa Cruz County to control sediment generation related to timber operations.

47. James, Cajun. October 2004. **Water Quality Effectiveness Monitoring for the Judd Creek Watershed.** Version 1.5. Prepared for Sierra Pacific Industries and the California Department of Forestry and Fire Protection, Monitoring Study Group.

Objectives:

i. To assess whether the Forest Practice Rules adequately protect water quality.

ii. To examine the response of water quality in Judd Creek due to intensive upload forest management activities.

iii. To characterize the changes in the spatial and temporal variability of the streamflow, turbidity and suspended sediment transport regimes for Judd Creek before and after timber harvest operations to determine the effect of the forest management practices implemented on water quality.

iv. To identify primary sediment sources and their relative volumetric contributions to the sediment budget.

v. To evaluate the impact of stream crossing reconstruction, road abandonment, and new road construction on turbidity above and below treatment sites.

vi. Data collected from five water quality stations, four flumes, grab samples and photo points will be included for analysis.

vii. The monitoring project will be implemented over a five-year period and includes six phases beginning in year 2004 and lasting at least through winter 2008.

viii Additional baseline data available from other research projects within the watershed will be used to verify that changes in response variables over time and space resulted from the timber harvest activities implemented in this monitoring project.

Key Findings:

- Contact the following persons for current information from this study:
    - Peter H. Cafferata, Forest Hydrologist, California Department of Forestry and Fire Protection, P.O. Box 944246, Sacramento, CA; (916) 653-9455
    - Cajun James PhD, Research and Monitoring Manager, Sierra Pacific Industries, P.O. Box 496014, Redding, CA; 96049-6014; (530) 378-8000

Relevancy:

1. Providing information about the effectiveness of Forest Practice Rules within the Judd Creek Watershed.

2. Providing baseline information on the changes in the spatial and temporal variability of the streamflow, turbidity and suspended sediment transport regimes for Judd Creek.

3. Assessing the impact of timber management practices employed within this watershed on water quality.

48. Klamt, Robert R., C. LeDoux-Bloom, J. Clements, M. Fuller, D. Morse, and M. Scruggs (multidisciplinary team leads). March 2003. **Gualala River Watershed Assessment Report**. North Coast Watershed Assessment Program, California Resources Agency and California Environmental Protection Agency, Sacramento, CA.

Objectives:

i. To help evaluate the effectiveness of various resource protection programs over time.

ii. To help focus watershed improvement programs, and assist people to develop successful projects that improve freshwater habitat and lead to improved salmonid populations.

iii. To "protect the best" watersheds and streams through watershed stewardship, conservation easements, and other incentive programs.

iv. Provide assessment information to help landowners and agencies better implement laws that require specific assessments such as the State Forest Practice Act, Clean Water Act, and State Lake and Streambed Alteration Agreements.

Key Findings:

- [Erosion/Sediment] Most of the Gualala River Watershed has improved from 1984 to 1999/2000, based on aerial photo interpretation of accumulations of sediment that were interpreted as indicative of channel disturbance. Since 1984, total erosion from upslope areas has not resulted in a net increase of sedimentation within the majority of the tributaries.

- [Instream Habitat] Increasing the instream habitat complexity is the top recommendation category for all of the subbasins. Table 3-3 (*Gualala River Watershed - Stream Characteristics Representing Sediment Sources or Storage*) shows that the amount of disturbed stream channels was reduced by over 47% between 1984 and 2000.

- [Riparian/Water Temp] Water temperatures are suitable in the smaller tributaries for which they had data.

- [Gravel/Substrate] Available data from sampled streams suggests that suitable spawning gravel for salmonids is limited in some streams, and abundant in others.

- [Other] Salmonid habitat conditions are the best in the North Fork Subbasin. Macroinvertebrate surveys indicate generally good conditions.

- Harvest of coastal redwood and Douglas-fir actively occurs with substantially improved practices. While some areas of the watershed experienced more improvement than others during this period, an overall trend towards improvement in the transport reaches was observed.

- Forest thinning from below can be used to develop large riparian conifers for natural large woody debris recruitment and to hasten the development of a denser, more extensive and diverse riparian canopy.

- In the North Fork Subbasin, tributary water temperatures were mostly in the suitable ranges, with many deemed as "fully suitable" and macroinvertebrate surveys indicate generally good conditions.

- In the Gualala Mainstem/South Fork Subbasin, moderately to fully suitable water temperatures for the period of record (1994-2001) were observed in McKenzie Creek in the upper Subbasin, and Little and Big Pepperwood Creeks and Groshong Gulch in the lower Subbasin.

Cumulative Effects of Multiple Timber Harvest Plans:

- The consequence of active timber harvesting conducted in the watershed since 1990 indicates that contemporary timber operations did not preclude recovery in both fluvial geomorphic stream channel characteristics and riparian canopy cover.

- Between 1991 to 2001, 45,070 acres or 24% of the watershed has been subject to Timber Harvest Plans. THPs have been particularly concentrated in the North Fork, Rockpile, and Buckeye subbasins. Between 1991 and 2001, 38% of the North Fork subbasin has been subject to Timber Harvest Plan activities, 63.3% in the Rockpile subbasin, and 32.2% in the Buckeye subbasin. Timber harvest operations include road building, use, and maintenance associated with the active Timber Harvest Plans. These operations have taken place during the period where CGS NCWAP mapping documents a 30 to 40 per cent improvement in detrimental sediment storage or source attributes between 1984 and 1999/2000. Similarly, riparian canopy cover continued to improve from the mid-century bank to bank clearance operations. By the end of the tractor era in 1968, a range of 40 to 70 percent bank exposure gradually improved to approximately 25% by 1999/2000.

- The study documented long-term trends in overall watershed conditions. None of the improving trendlines have been reversed by any concentration of Timber Harvest Plan activities between 1991 and 2001. This contradicts certain projections of recent land use for cumulative effects by which a high density of Timber Harvest Plans may trigger adverse cumulative impacts in excess of the individual potential contributions from each project alone. No such cumulative processes from any collection of Timber Harvest Plans were realized in the Gualala watershed.

- Only the mid-century tractor operations caused a heavy concentration of multiple impacts as documented with this study. These can be inferred to be cumulative, and in excess of individual contributions. The mid-century storms generated the greatest collective impacts discharged from the large block areas cleared by tractors using the streamside road networks.-Harvest operations comprised a total of 47% of the North Fork, 61% of the Rockpile, 65% of the Buckeye, and 30% of the Wheatfield by 1964. The resulting extreme channel aggradation directly impaired anadromous habitat as a cumulative effect from the large-scale land use operations upslope. This contrasts with more dispersed land use patterns in 1942, indicated by photo sets dating to this time. Tractor operations were just starting, limited to small scattered block removals along the lower Wheatfield. Few debris slides were noted, and in channel conditions appeared undisturbed.

- Analysis for cumulative effects is extremely limited by the inherent variability of cause and effect relationships through time and space. The large storm events are responsible for most of the watershed damage. When these occur is a function of unpredictable weather conditions, rather than any threshold triggered by cumulative land use. This study shows that basic assumptions underlining cumulative effects need to be reevaluated in the context of longer term watershed trends interrupted by broad-scale disturbances, including storm events and earthquakes, and how improper land use practices may accelerate the effects of unpredictable, broad-scale natural disturbances.

Relevancy:

1. Despite timber harvesting in "threatened and impaired" watersheds, most ecological indicators were good or fully suitable.
2. Forest practices over the past 20 years have contributed toward overall improvement in stream reaches.
3. No negative cumulative impact processes from any collection of Timber Harvest Plans were realized in the Gualala watershed from 1991 to 2001.

49. Lewis, T.E., D.W. Lamphear, D.R. McCanne, A.S. Webb, J.P. Krieter, and W.D. Conroy. 2000. **Regional assessment of stream temperatures across northern California and their relationship to various landscape-level and site-specific attributes.** Forest Science Project, Humboldt State University Foundation, Arcata, CA. Technical Report.

Objective:

i. Characterize water temperature regimes and factors across a broad geographic area in northern California using continuous temperature data from streams throughout northern California.

Key Findings:

- Watersheds that are predominately coastal have cooler air temperatures whereas those that have a southeasterly to northwesterly orientation show strong thermal gradients.
- Water temperatures have a tendency to increase with increasing distance from the watershed divide and with increasing drainage area.
- Water temperature near the source is the coolest, normally close to groundwater temperature.
- The “threshold distance” concept, that is the distance from the watershed divide at which streams become too wide for riparian vegetation to provide adequate shading, was explored empirically using the continuous temperature data from streams throughout northern California.
- The data suggests that 43 miles is the approximate theoretical maximum threshold distance.

Relevancy:

1. A single temperature standard is difficult to apply to a broad region, because streams differ markedly in size, drainage area, elevation, geographical location, prevailing climatic conditions, aspect, riparian vegetation, etc.
2. Streams in diverse settings behave very differently, and temperature standards, whether numeric or narrative, should reflect these differences.

50. MacDonald, Lee H., Drew Coe, and Sam Litschert. 2003. **Measuring and Modeling Cumulative Watershed Effects.** College of Natural Resources, Colorado State University, Fort Collins, CO.

Objective:

i. To assess the limitations for quantifying cumulative watershed effects of timber harvesting.

Key Findings:

- Unpaved roads, high-severity fires, and mass movements are dominant sources of sediment in forested areas.
- Very high variability between sites and between years.
- Most roads are not connected to streams except at stream crossings.
- Relatively few sites contribute most of the sediment to the stream network.
- Need improved models to assess and predict cumulative watershed effects.
- Model calculations and predictions are just that; empirical models sensitive to the data set used for model development.
- Model validation difficult at both site and watershed scale.
- Implication is that we should focus on minimizing the effects of each action at the local scale.

Relevancy:

1. Cumulative watershed assessment procedures are unable to provide results on an absolute scale due to: imperfect landscape knowledge; problems of quantifying cause-and effect relationships; and inability to validate complex models.
2. The report questions whether it is appropriate for FPRs to be regulating cumulative effects if we do not have the capability of assessing or managing the resources of concern.

51. Mader, Steve. July 2001. **Supplemental Cumulative Effects Analysis; THP 1-00-101 MEN.** Prepared for Gualala Redwoods, Inc. CH2M HILL, Inc., Portland, OR.

Objectives:

i. To describe the potential "Other" cumulative effects of Gualala Redwoods Inc.'s (GRI) Cassidy THP (1-00-101 MEN), in addition to watershed, soil productivity, biological resources, recreation, visual resources, and traffic effects categories.

ii. Recommendation 1.v. of CDF's May 25, 2000 Preharvest Inspection #1 for the Cassidy THP stated, "The RPF shall revise the THP to address "Other" in the cumulative impacts assessment, either by stating "None" or describing other potential resource subjects at risk to accurately describe the items checked on THP page 51."

iii. To answer the question: Will "Other" impacts from this project, when combined with "Other" impacts from past and future projects, increase the total amounts of impact to a point that significant negative cumulative effects occur?

iv. "Other" effects were defined to include: watershed disturbance patterns (fluvial disturbances, forestry projects, erosion and sediment delivery, large woody debris), riparian microclimate, aquatic insects, water temperature, beneficial uses, relationship between floodplain forest function and upland forest function, and forest recovery.

Key Findings:

- The supplemental cumulative impacts assessment concluded that significant negative cumulative effects to "Other" resources would not occur.
- The cumulative effect of past THP projects, the Cassidy THP, planned THPs, and LWD placement projects would be to increase actual and potential LWD in the North Fork of the Gualala River.
- The cumulative effect of riparian recovery, large-tree retention and recruitment, and active placement of LWD would result in positive cumulative effects.
- Considering the fact that there was no evidence that cumulative impacts had accrued from past actions, and the fact that proposed forest practices would comply with current California Forest Practice Rules with appropriate mitigation for potential THP-specific impacts, there was no basis for concluding that the proposed THP would result in significant adverse cumulative effects on "Other" resources.

Relevancy:

1. The FPRs should be explicit about the types timber harvesting effects they regulate. Cumulative effects of timber harvesting on watershed, soil productivity, biological resources, recreation, visual resources, and traffic are difficult enough to measure and evaluate, without considering the ambiguous and open-ended category of "Other" cumulative effects.

52. Matthews, Graham and Timothy Best. November 2004. **Project Scale Effectiveness Monitoring for the South Fork Wages Creek Watershed.** Version 2.0. Prepared for Campbell Timberland Management and California Department of Forestry and Fire Protection. Graham Matthews & Associates, Weaverville, CA.

Objectives:

i. To assess the effectiveness of the Forest Practice Program (i.e., the Rules and the Review Process) in protecting the beneficial uses of water.

ii. Characterize the streamflow, turbidity and suspended sediment transport regimes for Wages Creek, SF Wages Creek and tributary streams

iii. Identify primary sediment sources and their relative volumetric contributions to the sediment budget.

iv. Determine changes in turbidity regimes following timber operations relative to pretreatment conditions.

v. Determine the effect of stream crossing reconstruction on turbidity above and below treatment sites.

Key Findings:

- Contact the following persons for current information from this study:
  - Peter H. Cafferata, Forest Hydrologist, California Department of Forestry and Fire Protection, P.O. Box 944246, Sacramento, CA; (916) 653-9455
  - Stephen P. Levesque, Forest Hydrologist, Hawthorne Timber Company / Campbell Timberland Management P.O. Box 1228, Fort Bragg, CA; (707) 961-3302

Relevancy:

1. Providing information about the effectiveness of FPRs at the South Fork Wages Creek Watershed.

53. National Council for Air and Stream Improvement, Inc. (NCASI). 1999. **Scale Considerations and the Detectability of Sedimentary Cumulative Watershed Effects.** National Council for Air and Stream Improvement, Inc., Research Triangle Park, NC. Technical Bulletin No. 0776.

Objective:

i. To evaluate the extent to which sedimentary cumulative watershed effects (CWEs) are dependent on the spatial scale of the analysis. In reality, the effects of spatial scale cannot be separated from the temporal scale or measurement uncertainty. Thus, this report evaluates each of these factors as a guide to developing more effective monitoring programs and improving the predictability of sedimentary CWEs.

Key Findings:

- CWEs result from the overlapping effects of management activities in time or space. The routing and downstream accumulation of sediment from forest management activities is of particular concern because it directly affects key aquatic resources, and these sedimentary CWEs are often the most severe constraints on forest management activities. The prediction and detection of sedimentary CWEs is particularly difficult because of the complex interactions among temporal scale, spatial scale, and measurement uncertainty.

- Temporal scale considerations range from the short-term variability of sediment transport rates to the variability in annual sediment loads within a single basin. Short-term fluctuations in bedload transport rates commonly extend over one order of magnitude, and high-intensity sequential samples had an average coefficient of variation of 79% for near constant flow, and 95% when samples were taken during a high flow event. An analysis of existing data indicated that 13-95% of the variation in sediment transport rates could be explained by discharge.

  At the interannual scale, the coefficient of variation for annual sediment loads is typically at least 70-100%. There was a weak tendency for the interannual variability to increase with increasing annual sediment yields, but there was no indication that interannual variability decreased with increasing basin size. The distribution of annual sediment yields tended to be lognormal, although basins with lower annual sediment yields were often normally distributed. Given this variability, almost a decade of measurements are needed to determine the annual sediment yield to within 100% of the true value at the 95% confidence level.

- The effects of spatial scale range from the variability in sediment loads within a cross-section, to the variation in the amount of sediment transport along a downstream gradient, and the interbasin variability in annual sediment loads. Temporal and spatial scales are not easily separated, and knowledge of both spatial and temporal variability is necessary to efficiently allocate sampling effort. The short-term and small-scale variability problems are more severe for bedload transport than suspended sediment.

- Spatial scale issues are particularly important in terms of the downstream delivery of sediment and the reliability of interbasin comparisons. Sediment delivery ratios are not appropriate for routing different-sized particles through a sequence of varying stream types. An analysis of tracer data suggested that mean annual transport distances increase with gradient in braided or aggrading streams, but decline with gradient in steep, hydraulically rough streams. Although there are a series of problems with extrapolating from tracer studies, typical annual transport distances are estimated to be approximately 6, 1, and 0.1 mi for suspended sediment, sand, and coarse particles, respectively. These rates indicate that there will often be a substantial lag in the occurrence of a sedimentary CWE, and the timing and location of a sedimentary CWE is highly dependent on key factors such as the particle size of the sediment being introduced, the sequence of stream types, and the sedimentary state of the streams through which the sediment must pass.

- A series of interbasin comparisons indicated considerable variability in the strength of the correlation in annual sediment yields between adjacent undisturbed basins. Of particular concern was the observation that a slight shift in the years of comparison could greatly alter the strength and slope of the relationship between basins. This instability also extended to the relationship between various flow parameters (e.g., annual water yield) and annual sediment yields on a given basin.
- The uncertainty in detecting sedimentary CWEs is further compounded by the problems of accurately measuring sediment transport rates over a range of temporal scales. Since any sampler disturbs the flow lines in the stream, there is an inherent bias in the data and this varies as a function of particle size. Since we typically sample much less than one percent of the possible samples in time and space, sediment yield estimates require considerable extrapolation. Both summation and rating curve techniques are subject to bias, and a change in the calculation or bias-adjustment procedure can alter the estimated sediment yields by more than a factor of two. Unfortunately, sediment transport equations are even less accurate, and calculated sediment transport rates extremely sensitive to which equation is used and the value of the key input parameters.

Relevancy:

1. Taken together, these factors suggest that we should not expect to detect less than a twofold change in sediment transport rates or sediment yields.
2. Changes in measurement techniques, calculation procedures, or the period of comparison can create the appearance of a sedimentary CWE when none actually exists.
3. The inherent spatial and temporal variability suggests that at least 5-10 years of both pre- and post-monitoring are likely to be necessary to reliably detect a sedimentary CWE.
4. Since management decisions often cannot be delayed and longer-term monitoring projects cannot be implemented on all reaches of concern, alternative approaches are necessary. A geomorphic analysis of the current sedimentary state of the stream network is an essential first step towards any CWE analysis or monitoring effort. Modified sediment delivery ratios can be developed by considering, at a minimum, the sizes of the particles being introduced, as well as the sequence and condition of stream types. This basin-specific understanding is essential for determining the appropriate temporal and spatial scales for analysis and monitoring. A universal sedimentary CWE model is simply not realistic given the diversity and complexity of sediment production, transport, and delivery processes.

54. Sacramento River Watershed Program. June 2002. **Annual Monitoring Report: 2000-2001.** Sacramento River Watershed Program, Woodland, CA.

Objectives:

i. To review the Sacramento River Watershed Program (SRWP) monitoring effort and the data generated by the SRWP and other collaborating water quality monitoring programs (USGS NAWQA, Sacramento River Coordinated Monitoring Program, City of Redding NPDES Monitoring, Department of Water Resources intensive tributary monitoring program).

ii. To describe data water chemistry, aquatic toxicity, fish tissue, and bioassessment data.

iii. To evaluate the attainment of beneficial uses and potential impairment in surface waters of the Sacramento River watershed.

iv. To assess spatial and temporal distributions of a variety of important water quality characteristics.

v. To compare the relative contributions of different inputs to the Sacramento-San Joaquin Delta of selected parameters.

Key Findings:

- Page 85, Item iv (Conclusions and Recommendations): "There was a general trend for concentrations of several parameters (TDS, organic carbon, nutrients) to increase in concentration in the mainstem Sacramento River from upper watershed to lower watershed. This trend can be attributed to a combination of natural and anthropogenic sources, *and is moderated by high quality Sierra tributary inflows*."

Relevancy:

1. Forest streams derived from Sierra watersheds subjected to timber harvesting deliver high quality tributary inflows to the upper watershed of the mainstem Sacramento River. The inflows are low in TDS, organic carbon, and nutrients despite timber harvesting.

55. Schult, Dennis T. and Dale J. McGreer. August 2004. **Stream Temperature Modeling of the Gualala River Using the *Heat Source* Model.** Prepared for Gualala Redwoods, Inc. by Western Watershed Analysts, Clarkston, WA.

Objectives:

i. To model the effect of the Iris THP (THP No. 1-03-185 SON) riparian prescriptions on daily maximum water temperatures in the Gualala River Using the Heat Source model (Version 7.0).

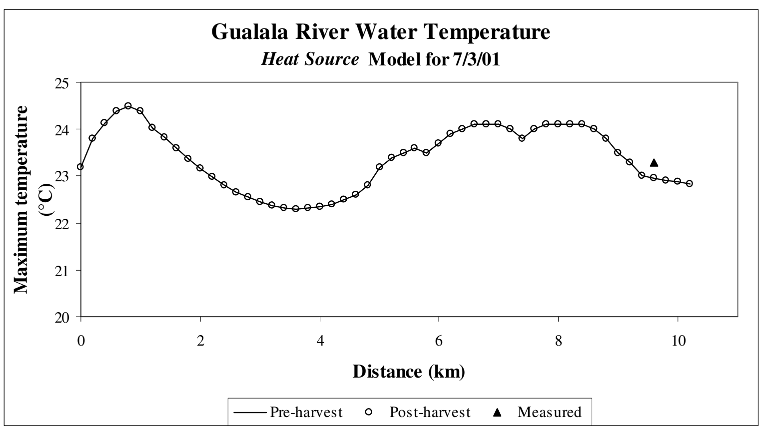
ii. Iris THP riparian prescriptions include: no harvest within 30 feet of the streambank; maintain 85% canopy density from 30 to 75 feet from the streambank; maintain 65% canopy density from 75 to 150 feet from the streambank; and no harvest along opposite streambank.

iii. July 3rd was selected for modeling because the warmest water temperatures for 2001 were recorded on this date.

Key Findings:

- Results demonstrated that the harvest proposed by Gualala Redwoods, Inc. for the South Fork Gualala River, in accordance with the Iris THP riparian prescriptions, would not impact water temperatures.

- The modeling revealed no discernible differences between the pre-harvest and post-harvest stream temperatures, as evidenced by essentially identical observation points for pre-harvest and post-harvest (Figure).



Relevancy:

1. Riparian harvest prescriptions can be developed that avoid measurable impacts to water temperatures.

2. The Heat Source model (Version 7.0) can be used to test the sensitivity of alternative FPRs that recognize the physical limitations of riparian area attributes to influence stream temperature.

56. Spittler, T.E. June 2004**. THP 1-04-032 MEN (Lily) Information Needed to Review Activities on Floodplains.** Department of Conservation, California Geological Survey, Santa Rosa, CA.

Objective:

i. To address environmental factors of concern, potential timber harvesting impacts, and mitigations to minimize the potential for adverse environmental impacts while fostering watershed recovery after timber harvesting in a riparian area.

Key Findings:

- Stream temperature may not be a significant issue for units where trees on the north side of the watercourse are proposed for harvest in WLPZ.
- Floodplain erosion typically is not a major process because floodplains are dominantly depositional areas.
- Actively eroding overflow channels appear to have been formed along old river-parallel roads and skid trails.
- Timber harvesting in redwoods that do not involve conversion or construction of graded surfaces rarely decrease surface roughness or sediment filtering because there is a net increase in the surface area of low-growing vegetation, stems, and litter.
- The 30-foot no-cut buffer would have no effect on recruitment of large wood into the current active channel.
- The Gualala River has remained remarkably stable for over 60 years despite timber harvesting.
- Neither peak nor base flows are likely to show detectable changes after timber harvesting.

Relevancy:

1. Riparian timber harvesting has undetectable negative effects, and may have positive effects, on riparian functions.
2. The greatest ecological concern for timber harvesting in the riparian area is the erosive effect of legacy roads, which may be mitigated through the THP.

□□□

57. Tesch, Steven D. (ed.). February 2005. **Fish and Wildlife Habitat in Managed Forests Research Program Progress Reports FY 2005 (July 1, 2004 - June 30, 2005).** College of Forestry, Forest Research Laboratory, Oregon State University, Corvallis, OR.

Objective:

i. To compile progress reports from the projects and activities that are part of the FRL research program on fish and wildlife habitat in managed forests.

Key Findings:

- The report summarizes new and ongoing forest practices research at Oregon State University on topics such as:
    - *Effect of Road Characteristics and Road/Stream Connectivity on Delivery of Sediment to Streams*
    - *Influence of Riparian Vegetation and Stream Condition on Water Quality After Timber Harvest on Non-Fish-Bearing Headwater Streams*
    - *Contributions of Riparian Vegetation to Terrestrial and Aquatic Food Chains: Contrasting Alder and Douglas-fir Riparian Forests*
    - *Habitat Conservation for Stream Amphibians in a Managed Forest Landscape*
    - *The Hinkle Creek Paired Watershed Study: The Effect of Timber Harvesting Adjacent to Non-Fish-Bearing Headwater Streams on Cumulative Water Quality Effects in Fish Bearing Streams*

Relevancy:

1. Contact Steven D. Tesch, Program Manager, or Hal Salwasser, Dean and Director College of Forestry and Forest Research Laboratory, for current scientific research results relevant to California forest practice rules.

58. Valentine, Bradley E. and Marc Jameson. February 1994. **Little North Fork Noyo Fishery Study, 1992.** California Department of Forestry and Fire Protection, Coast Cascade Region, Santa Rosa, CA.

Objective:

i. To replicate portions of Burns' (1970, 1971, 1972) work on the impacts of logging on salmonid fishes of the Little North Fork of the Noyo River in Mendocino County. Since then, logging continued under regulations that became increasingly more protective of aquatic habitat, although salmonid populations continued to decline.

Key Findings:

- Newts were captured at one site, but not in numbers sufficient to estimate population size. Yellow-legged frogs were captured in substantial numbers, but only at the downstream-most site. Sculpin were captured at 4 of 5 sites. Pacific giant salamanders, coho salmon, and steelhead rainbow trout were captured at each site. Of the three species captured at each station, dominance as measured either by populations or by biomass differed among sites. While the total salmonid biomass was similar for the 1992 and 1966-69 periods, the species composition inverted from primarily coho salmon to primarily steelhead trout. Steelhead populations followed a negative curvilinear relationship with percent fines; coho salmon biomass suggested a positive curvilinear relationship with the substrate's geometric mean diameter. Of the factors evaluated, none clearly could be linked with the inversion of salmonid species.

- During the logging activities of the 1966-69 period, the stream's width increased and depth decreased. By 1992, the stream depth had recovered, if not increased, while stream width was intermediate between the 1966-69 period. Pools greater than 30 cm residual depth were nearly always associated with large woody debris, either in the form of logs or in-place stumps. Shade canopy had recovered and was near maximum. Large woody debris was limited and showed evidence of prior removal.

- Sediment quality, measured as percent fines < 0.85 mm, was intermediate to the 1966-69 period, and provided estimates of 30% and 50% survival-to-emergence for coho and steelhead, respectively. However, the true survival-to-emergence value of the streambed was greater because no correction factors were applied for wet-sieving or the winnowing of fines.

- During the 1966-69 period, the percent of substrate comprised of particles less than 0.85 mm averaged 20.0 prior to timber harvest activities and jumped to greater than 30% after harvest—a statistically significant increase in fines from pre- to post-logging years—but the 1992 average fell between the pre-logging and post-logging values, suggesting some recovery of fines in the substrate at the pool riffle crests. The authors stated, "the fact that the level of fines was as low as it was despite and extended, multi-year drought and ongoing timber harvest is surprising." Supplemental 1993 samples exhibited lower concentrations of fines than did the 1966-69 period's pre-logging values.

Relevancy:

1. Data suggest that fish habitat quality recovered to pre-logging conditions during prolonged timber harvesting under improved forest practices rules over a 23-year timeframe.

2. At a coarse level, steelhead and coho have similar habitat needs (cool, clear water; clean gravels; spawning access; rearing habitat). The fact that the salmonid biomass was similar despite prolonged timber harvesting under improved rules to reduce fine sediment delivery suggests that forest practices in the Little North Fork Noyo River watershed were not destructive to the cold-water fishery habitat.

59. Yee, Carlton S. April 2003. **California's Forest Practices and Environmental Quality. Response to California State Senate Natural Resources Committee Report on Forest Policy Alternatives; and the California State Senate Office of Research Report on Timber Harvesting and Water Quality.** Commissioned by Forest Products Industry National Labor Management Committee, California Chapter.

Objective:

i. To respond to allegations and assumed problems in the forests of California; assumed problems with little or no evidence to support the claims.

Key Findings:

- The cost of conducting forestry business in California has increased to the point that some companies are curtailing future investments or divesting in the state.
- The CA FPA protects water quality through harvest planning, environmental analysis, regulation, enforcement, research, and monitoring.
- The CA FPA protects aquatic and terrestrial threatened and endangered species.

Relevancy:

1. California forest practices are protecting environmental quality and have adapted to meet new needs and requirements.

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